TASK FORCE REPORT

SCIENCE AND TECHNOLOGY

A Report to
THE PRESIDENT'S COMMISSION ON LAW ENFORCEMENT AND ADMINISTRATION OF JUSTICE

Prepared by
THE INSTITUTE FOR DEFENSE ANALYSES

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Copies of the Commission's general report, "The Challenge of Crime in a Free Society," can be purchased from the Superintendent of Documents for $2.25.
Copies of other task force reports and other supporting materials can also be purchased.

FOREWORD

In February of this year the President's Commission on Law Enforcement and Administration of Justice issued its General Report, *The Challenge of Crime in a Free Society.* As noted in the Foreword to that Report, the Commission's work was a joint undertaking, involving the collaboration of Federal, State, local, and private agencies and groups, hundreds of expert consultants and advisers, and the Commission's own staff. Chapter 11 of that Report made findings and recommendations relating to the possible contributions of science and technology to the problems of criminal justice.

This volume, the Task Force Report on Science and Technology, embodies the research and analysis which underlie those findings and recommendations, and in many instances it elaborates on them. As noted in the Preface, the Institute for Defense Analyses (IDA) with funding from the Office of Law Enforcement Assistance of the Department of Justice, undertook the responsibility for organization of the Science and Technology Task Force for the Commission. Thus, this volume represents the report of IDA to the Commission and reflects the work of IDA with advice and assistance from some members of the Commission and its staff.

The Commission is grateful to IDA for undertaking this important task and to those who worked on this volume including consultants, advisers and collaborating agencies whose efforts are reflected in this volume.

NICHOLAS DEB. KATZENBACH,
Chairman.

Preface

This report of the Science and Technology Task Force of the President's Commission on Law Enforcement and Administration of Justice was prepared by the Institute for Defense Analyses (IDA). The material in it is intended to supplement and amplify the discussion of science and technology in the general report of the Commission to the President, "The Challenge of Crime in a Free Society," which contains the Commission's recommendations. The work was conducted under a grant from the Office of Law Enforcement Assistance of the Department of Justice to the Institute for Defense Analyses through the Department of Defense. The staff for the study were brought together from industry, universities, government, and IDA. The major portion of the work was conducted during the summer and fall of 1966.

Its preparation by an outside organization and the technical nature of its subject matter distinguish this report from the other works of the Commission. Some of the major thrusts and the general coverage of the Task Force's work were discussed by the Commission members, and the Commission's staff advised and consulted with the Science and Technology Task Force staff during all of its work. But the substance of the report was the responsibility of IDA.

A special Science Advisory Committee was established by the Attorney General to help focus the Task Force's work on the important problems, to assist in many of the professional judgments, and to review the scientific validity of the work. The members of that Committee are:

Hon. Charles D. Breitel, Associate Judge, Court of Appeals of the State of New York and Member, President's Commisssion on Law Enforcement and Administration of Justice.

Dr. James Fletcher, President, University of Utah.

Dr. Eugene Fubini, Vice President, International Business Machines, Inc.

Chief Thomas Reddin, Chief of Police, Los Angeles Police Department.

Dr. Robert Sproull, Vice President for Academic Affairs, Cornell University.

Professor James Q. Wilson, Department of Government, Harvard University.

Prof. Adam Yarmolinsky, Harvard Law School, Harvard University.

In addition, Dr. David Robinson, of the Office of Science and Technology in the Executive Office of the President, participated regularly and served in effect as an eighth member.

At IDA, general supervision of the Task Force was provided by Dr. Milton U. Clauser and Dr. Ali B. Cambel, the directors of IDA's Research and Engineering Support Division, and Mr. Alexander J. Tachmindji, Assistant Director.

The work of the Task Force was under the overall direction of Dr. Alfred Blumstein and was prepared as an integrated effort by the staff and a number of consultants. The regular members of the staff and the subjects they covered were:

Mr. Ronald Christensen, University of California, systems analysis and corrections operations.

Mr. Ronald Finkler, Institute for Defense Analyses, information systems.

Dr. Saul I. Gass, International Business Machines, police operations.

Mrs. Sue Johnson, consultant, systems analysis.

Dr. Peter Kelly, Kelly Scientific Corp., communications and electronics.

Mr. Raymond Knickel, consultant, police electronics equipment.

Mr. Richard Larson, Massachusetts Institute of Technology, systems analysis.

Dr. Joseph Navarro, Institute for Defense Analyses, court operations.

Miss Jean Taylor, Institute for Defense Analyses, court operations.

In addition to this basic staff a number of consultants undertook separate studies in close coordination with the staff:

Prof. Thomas Bartee, Harvard University, fingerprint recognition.

Prof. Mandell Bellmore, Johns Hopkins University, operations research.

Mr. Albert Bush-Brown, Rhode Island School of Design, city planning.

Mr. Joseph Coates, Institute for Defense Analyses, nonlethal weapons.

Mr. P. A. DonVito, consultant, cost analysis.

Mr. Leonard Goodman, Bureau of Social Science Research, attitude survey.

Mr. Norbert Halloran, International Business Machines, court information systems.

Dr. William Herrmann, consultant, police operations.

Mr. Herbert Isaacs, consultant, survey of police field operations.

Mr. Robert Jones, C-E-I-R, information systems.

Dr. Vincent Keenan, consultant, laboratory instrumentation.

Prof. Peter Lejins, University of Maryland, criminology.

Dr. William Offutt, International Business Machines, court operations.

Mr. Lloyd Perper, consultant, alarms.

Prof. Thomas Schelling, Harvard University, economic analysis.

Mr. Peter Szanton, Bureau of the Budget, program budgeting.

Dr. Claude Walston, International Business Machines, information systems.

Prof. Leslie Wilkins, University of California, criminology.

The work of the staff and of these consultants is reflected in the main body of this report. Ten of the specific papers generated are presented as appendices A through J. Additional papers on apprehension by police, nonlethal weapons, the overall criminal justice system, delay in courts and information flow are more extensive and technical to be presented here. These reports are now in preparation and will be available from the Clearinghouse for Federal Scientific and Technical Information of the National Bureau of Standards. Papers on computer operations in the courts, on economic analysis of organized crime, on the design of national criminal justice statistical systems, and on the projection of populations under correctional supervision appear as appendices in the Task Force reports on Courts, Organized Crime, Assessment of Crime, and Corrections, respectively.

Since the Task Force staff of scientists and engineers had little prior knowledge of criminal justice operations and problems, it relied heavily on the Crime Commission staff and numerous criminal justice officials for identification of the operational problems of the system.

The Federal Bureau of Investigation was extremely helpful in this regard, especially in providing data on crime in the United States. Among State agencies, the California Bureau of Criminal Statistics and the New York State Identification and Intelligence System also made valuable contributions.

The police departments of Baltimore, Boston, Chicago, New York, Los Angeles, San Francisco, St. Louis, and Washington, D.C., among others, were generous in their counsel and provided staff members with some operational experience in patrol, communications, and other police functions. The International Association of Chiefs of Police was a valuable source of data and advice.

Experience and data on court operations were provided by the Court of Common Pleas of Allegheny County, Pa., the courts in the District of Columbia, and the Administrative Office of the U.S. Courts. Similar contributions in corrections came from the Federal Bureau of Prisons, the California Youth and Adult Authorities, the Draper Correctional Center, Lorton Reformatory, and the National Training School for Boys.

Scientists and engineers from industry, government, and universities contributed many suggestions and provided many of the needed technical details. In the Federal Government, the Federal Bureau of Investigation, the Federal Communications Commission, the Institute of Telecommunication Sciences and Aeronomy, and the Agency for International Development were among the agencies providing valuable advice and information. A number of companies in the electronics, data processing, telephone, and automobile industries were especially helpful.

A number of individual consultants provided data or guidance, reviewed preliminary papers, and generally assisted in the work of the Task Force. Among others too numerous to mention, this group included:

Miss Sylvia Bacon, Assistant Director, President's Commission on Crime in the District of Columbia.

Mr. James E. Barr, Chief, Safety and Special Radio Services Bureau, Federal Communications Commission.

Mr. Ronald Beckman, Research and Design Institute.

Mr. Richard Braun, Criminal Division, Department of Justice.

Mr. Robert Brooking, Communications Engineer, City of Burbank, Calif.

Mr. Jerome Daunt, Chief, Uniform Crime Reporting Section, FBI, Department of Justice.

Dr. Robert Emrich, Office of Law Enforcement Assistance, Department of Justice.

Hon. Richard F. C. Hayden, Judge of the Superior Court of Los Angeles.

Dr. Jerry Kidd, National Science Foundation.

Mr. Richard McGee, Administrator, Youth and Adult Corrections Agency, Sacramento, Calif.

Mr. Robert Muzzy, Research Associate, Ohio State University.

Dr. Jesse Orlansky, Institute for Defense Analyses.

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Mr. Arnold Sagalyn, Director, Office of Law Enforcement Coordination, Department of Treasury.

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Dr. Michael Watter, Institute for Defense Analyses.

Mr. Herbert Weiss, Litton Systems, Inc.

Prof. Marvin Wolfgang, Director, Center of Criminological Research, University of Pennsylvania.

Computer programming assistance was provided by Thomas Celi, Robert Cohen, Janice Heineken, Thomas Humphrey, Charles McBride, Franz Nauta, and Vera Wilson. Additional research assistance was provided by Mary Ellen Angell, Mara Auerbach, Lois Martin, Marsha Smith, and Ray Vickery.

Secretarial and general administrative operations were coordinated by Carolyn Tillman. She was assisted by many members of the IDA secretarial staff.

Editorial assistance was provided by Edgar Boling, Richard Brennan, Thomas Farrell, Joyce Harmon, Henry Parrish, and Marvin Walter. Illustrations were prepared under the direction of Richard A. Cheney and Walter J. Hamilton by Edward S. Gault and Vernon Townsend.

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TABLE OF RECOMMENDATIONS

This Table of Recommendations is reprinted from the general report of the Commission, "The Challenge of Crime in a Free Society." It lists the Commission's recommendations on science and technology and shows where in this volume each is treated in more detail.

Science and Technology and the Criminal Justice System

ROLE OF SCIENCE AND TECHNOLOGY IN CRIMINAL JUSTICE

The natural sciences and technology have long helped the police to solve specific crimes. Scientists and engineers have had very little impact, however, on the overall operations of the criminal justice system and its principal components: police, courts, and corrections. More than 200,000 scientists and engineers have applied themselves to solving military problems and hundreds of thousands more to innovation in other areas of modern life, but only a handful are working to control the crimes that injure or frighten millions of Americans each year. Yet, the two communities have much to offer each other: science and technology is a valuable source of knowledge and techniques for combating crime; the criminal justice system represents a vast area of challenging problems.

EQUIPMENT

In the traditional view, science and technology primarily means new equipment. And modern technology can, indeed, provide a vast array of devices beyond those now in general use to improve the operations of criminal justice agencies, particularly in helping the police deter crime and apprehend criminals. Some of the more important possibilities are:

- ☐ Electronic computers for processing the enormous quantities of needed data.
- ☐ Police radio networks connecting officers and neighboring departments.
- ☐ Inexpensive, light two-way portable radios for every patrolman.
- ☐ Computers for processing fingerprints.
- ☐ Instruments for identifying criminals by their voice, photographs, hair, blood, body chemistry, etc.
- ☐ Devices for automatic and continual reporting of all police car locations.
- ☐ Helicopters for airborne police patrol.
- ☐ Inexpensive, reliable burglar and robbery alarms.
- ☐ Nonlethal weapons to subdue dangerous criminals without inflicting permanent harm.
- ☐ Perimeter surveillance devices for prisons.
- ☐ Automatic transcription devices for courtroom testimony.

Many of these devices are now in existence, some as prototypes and some available commercially. Others still require basic development but are at least technically feasible and worthy of further exploration.

But for many reasons, even available devices have only slowly been incorporated into criminal justice operations. Development funds have been scarce, industry has only limited incentive to conduct basic development for an uncertain and fragmented market, and criminal justice agencies have very few technically trained people on their staffs. Much closer communication is needed between criminal justice officials and engineers[1] to identify the problems for the engineers and to enumerate the possibilities for the officials' consideration.

Also, conventional methods of governmental budgeting often tend to restrict the application of new technology. Budgets are traditionally prepared with item categories such as "personnel" and "equipment," rather than with functional or program categories, such as "maintaining general police patrol." Under such circumstances, a reasonable equipment expenditure may loom as a large increase in the equipment budget. For instance, if each car in a 50-vehicle fleet is provided with a $200 piece of equipment, the additional $10,000 might dominate the increase in an item budget. When it is considered, however, that it costs about $100,000 per year to operate a two-man patrol car continuously, an investment of even a few thousand dollars per car, amortized over at least 3 years, is a small cost if it significantly improves patrol operations. Compared to a $5 million budget for "patrol," a $10,000 increment is very small.

The Federal Government, as well as some State and local governments, is moving from item budgeting to program budgeting to obtain a clearer picture of how its resources are being allocated. Such an approach seems particularly appropriate for criminal justice agencies, especially as their operations become more interrelated in a criminal justice system.[2]

In the realm of technology it is far easier to imagine interesting possibilities than to choose the ones in which to invest necessarily limited equipment funds. Technology can fill most reasonable requests and can thereby

[1] To initiate this dialogue, the Commission sponsored a Symposium on Science and Criminal Justice in Washington, D.C., in June 1966. The proceedings are available from the Superintendent of Documents. A subsequent symposium was held in Chicago in March 1967, sponsored by the Office of Law Enforcement Assistance and the Illinois Institute of Technology Research Institute. Proceedings are to be published by the latter organization.

[2] An illustrative program budget for criminal justice functions is presented as appendix A.

provide considerable help to law enforcement. But society must decide what devices it wants relative to the price it is willing to pay in dollars, invasion of privacy, and other intangible social costs. It is technically feasible, for example, to cut auto theft drastically by putting a radio transmitter in every car in America and tracking them all continuously. But this might cost a billion dollars and could create an intolerable climate of surveillance. Science can provide the capability, but the public as a whole must participate in the value discussion of whether or not the capability is worth the costs.

This is often a difficult decision to make, since for most inventions, no one can now say what they will do about crime—very little being known of what *anything* will do about crime. Inventions can cut costs or they can increase man's ability to sense and to act. They provide more options. They make possible actions heretofore impractical. But their value in reducing crime is not known and will remain so until careful field evaluations are conducted. There should be a coordinated national program to identify the equipment requirements, to undertake the most promising developments, and then to conduct field trials that measure intended as well as side effects of new equipment and procedures. The results of these research, development, test, and evaluation efforts must then be disseminated widely so that the entire system can share in the benefits.

INFORMATION AND RESEARCH

One essential for such a research program, as well as for immediate operational improvements, is better information about crime and the criminal justice system. Criminologists, criminal justice officials, and others familiar with the problems of crime control have long emphasized that the lack of adequate, complete, and timely information lies at the root of many of their problems. Information is needed about:

- ☐ The extent and nature of crime and its causes, to help in formulating effective crime control programs.
- ☐ Current crimes, to aid in immediate apprehension of offenders.
- ☐ Past crimes, to help solve them.
- ☐ Individual offenders, to help prescribe treatment for them.
- ☐ Criminal justice operations, to help officials better allocate their money and manpower.
- ☐ Effects on crime of actions taken by the criminal justice system, to help promote the evolution of a more humane and effective system.

Each year, judges in this country pass approximately 2 million sentences; unfortunately, no one knows the likely effect of the sentences on future criminal behavior. The Nation's policemen spend half of their time on "preventive" patrol, yet no police chief knows how much crime is thereby prevented. Corrections officials, responsible for over 2 million offenders each year, are considering many new treatment programs; to choose among these, they must be able to estimate the amount by which each program can reduce recidivism.

Information about the consequences of actions by the criminal justice system is essential for improving those actions. In this sense the criminal justice system may be compared to a blind man far down the side of a mountain. If he wants to reach the top, he first must move. And it matters little whether his first move is up or down because any movement with subsequent evaluation will tell him which way is up. A step by step process of experimenting, evaluating, and modifying must be undertaken. Both innovation and the subsequent evaluation of its consequences are essential to climbing up. This process is inherently slow and expensive, and it must be conducted with care to avoid misleading results.

Scientists can help by participating in the efficient design of experiments and the evaluation of their results. The fact-finding, analytical, and experimental methods of science can help develop the required information. Once the information is developed, then the modern technology of data collection, retrieval, analysis, and transmission can help process and deliver it where and when it is needed.

Such carefully controlled testing offers some valuable opportunities for making the criminal justice system more efficient and effective. Correctional agencies have experimented with assigning at random a test group of offenders to each of several different treatment programs and evaluating their relative effectiveness in terms of recidivism and social adjustment. The same experimental techniques are being used in the evaluation of drugs and other treatment by the medical sciences. Similarly, police departments can control the distribution of marked and unmarked cars patrolling various precincts to evaluate the effects upon crime rates in these and adjoining precincts. The design of such experiments must be carefully undertaken to avoid spurious experimental effects and to avoid taking otherwise undesirable or unethical actions merely for the sake of the experiment.

Crime control, being largely a social problem, may appear to be outside the realm of the scientists' skills. Indeed, many aspects of the problem do fall outside their scope. The experience of science in the military, however, suggests that a fruitful collaboration can be established between criminal justice officials on one hand and engineers, physicists, economists, and social and behavioral scientists on the other. In military research organizations these different professions, working with military officers in interdisciplinary teams, have attacked defense problems in new ways and have provided insights that were new even to those with long military experience. Similar developments appear possible in criminal justice.

Research, emphasizing the social and behavioral sciences but including all the sciences, must be undertaken on an expanded and continuing basis. Manufacturing industry devotes at least 3 percent of its budget to research, development, test, and evaluation.[3] The Defense Department spends about $7 billion a year on research

[3] Based on data from "Basic Research, Applied Research, and Development in American Industry—1965"; National Science Foundation; November 1966.

and development, about 13 percent of its regular budget.[4] In contrast, as recently as 1965, the Justice Department was the only Cabinet department with no share of the roughly $15 billion Federal research and development budget.[5] The research and development budget in other criminal justice organizations is negligible. Even if only 1 percent of the criminal justice budget were earmarked for research and development, this would provide about $50 million, and several times that amount needs to be invested each year.

SYSTEMS ANALYSIS

Because of the enormous range of research and development possibilities, it is essential to begin not with the technology but with the problem. Technological efforts can then be concentrated in the areas most likely to be productive. Systems analysis is a valuable method for matching the technology to the need. It uses mathematical models of real-life systems to compare various ways of designing and using these systems to achieve specified objectives at minimum cost. This approach is particularly relevant in today's prolific technology, where the problem is less one of producing new devices than of choosing among the many potential opportunities.

These same techniques of systems analysis can often be helpful when applied to the design of some of the operations in police, courts, and corrections agencies, and to relating these parts to the overall criminal justice system. Such analyses provide a framework for study and for experimenting, as in a laboratory, with many possible alternatives prior to actual field implementation. Depending as they do on the development of appropriate data, these analyses stimulate careful collection and evaluation of information, and can thereby help locate critical areas for research.

The use of systems analysis was a major theme of the work of the Task Force. The approach begins with a broad look at the system's objectives and the possible methods for achieving them. The next step is to estimate the costs and benefits of each method for reaching the goal. The overall goals, however, are often difficult to relate in quantifiable terms to the alternatives under consideration. Thus, it is necessary to narrow the focus to those parts and aspects of the criminal justice system that are amenable to systems analysis, and then to present conclusions in appropriately qualified terms.

Despite these limitations, the systems analysis approach has the larger advantage of clarifying goals and making them explicit, drawing attention to ways of achieving them. Decision makers are thereby forced to make conscious choices among the values to be served. This process makes apparent what information is relevant to these choices and stimulates the collection of the appropriate data.

Figure 1 shows an example of the work of the Task Force along these lines—the use of systems analysis in finding how the police patrol force can better deter crime by shortening the time it takes to respond to a call for help. In the step diagram, the objectives are shown on the risers and the means for achieving them on the treads. The support for each of the steps is shown beneath it. By a sequence of analytical and empirical investigations, necessarily interlaced with assumptions and judgment, it was possible to proceed from a basic objective of the criminal justice system—reducing crime—to specific recommendations concerning new technology and operating procedures. There are, of course, other interests involved in the operations of the criminal justice system—protecting the innocent and safeguarding individual privacy, for example. But by narrowing the focus to the crime-reduction objective, it may be possible to suggest new strategies that can then be evaluated in the light of other and broader objectives.

Figure 1 starts with the principal objective of the criminal justice system, reducing crime. One means of doing this is by deterring people who might otherwise commit criminal acts. The police deter primarily by using the patrol force to pose a threat of apprehension, thereby raising the chances of penalties. Field data were collected and analyzed to determine the important factors that lead to apprehension. Among these, response time appeared to be important. This led to a cost-effectiveness analysis which compared means for cutting response time. The results of the analysis suggested that the best allocation of resources would be in automating the communications center operations by such means as using computers to perform some of the dispatching functions, automatic car locaters to find the closest car, and other related technological possibilities. These components then can be brought together into a system design. Thus, it was possible to proceed systematically from the broad objectives down to the relevant technological details.

Of course, figure 1 is a highly simplified routing through the process. At each stage, the objectives are much more complex and the means far more numerous than the ones shown. In addition, the support for each step in this example is based on very preliminary work and requires much further development before firm conclusions can be drawn. Furthermore, this work was based on both specific and hypothetical situations, and the conditions examined may not necessarily apply in any given local situation. They are intended more as an illustration of an approach than for the generality of their conclusions.

THE SCIENCE AND TECHNOLOGY TASK FORCE

WORK OF THE TASK FORCE

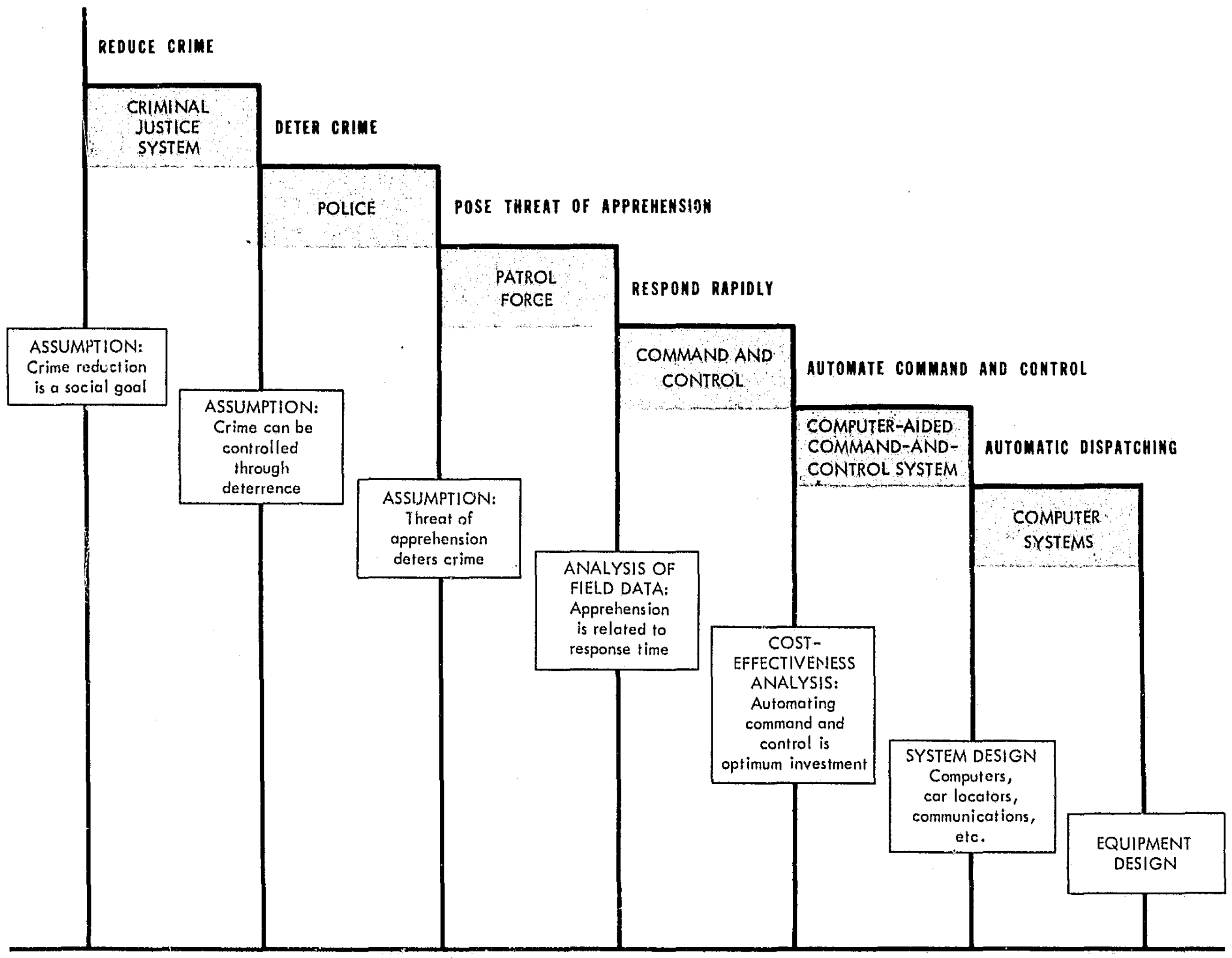
The Science and Technology Task Force was established to investigate in greater detail some of the applications of science and technology to the problems of crime, and especially to improving the criminal justice system. The Task Force sought:

- ☐ To identify the problems, immediate and long-term, that science and technology is most likely to help solve, and to suggest the kinds of research and development needed.

[4] "The Budget of the United States Government"; Fiscal year ending June 30, 1968; Government Printing Office; Washington, D.C.

[5] "Federal Funds for Research, Development, and Other Scientific Activities—Fiscal Years 1964, 1965, and 1966"—vol. XIV; National Science Foundation: NSF65–10; Government Printing Office, Washington, D.C.

FIGURE 1. A SIMPLIFIED ILLUSTRATION OF A SYSTEMS APPROACH RELATING TECHNOLOGY TO CRIME CONTROL



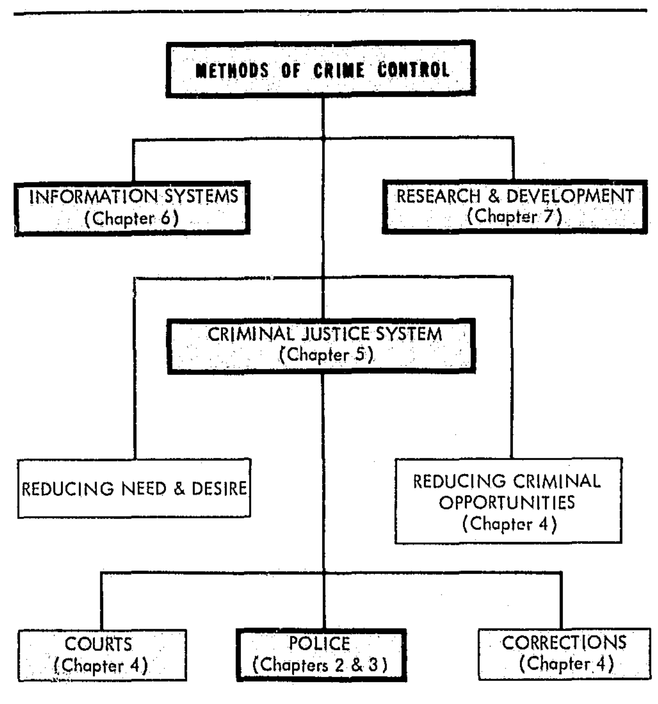
- ☐ To identify and describe crime control problems in a form more susceptible to quantitative analysis.
- ☐ To point out the kinds of important data on crime control and the criminal justice system that are lacking, unreliable, or otherwise unusable, and to propose means of correcting such deficiencies.
- ☐ To analyze problems in crime assessment, police, courts, and corrections as an aid to the Commission and its other task forces.
- ☐ To suggest organizational formats within which technical devices and systems can be developed, field tested, and rendered useful.

With a scope so broad and time and manpower severely limited, it was necessary to make an early selection of areas to be emphasized. The social and behavioral sciences were deemphasized, largely because these were subjects already receiving treatment elsewhere in the Commission's work. The system sciences—information systems and computer applications, communications systems, and systems analysis—were given primary emphasis. In examining the applicability of technology, the emphasis was placed on identifying requirements rather than on detailed design or selection among equipment alternatives.

Among crimes, the primary focus was on the "Index" crimes—willful homicide, forcible rape, aggravated assault, robbery, burglary, larceny of $50 and over, and auto theft—the predatory crimes which are a principal source of public concern today. Only limited attention was paid to public disorder and vice crimes, and to "white collar crimes," such as illegal price fixing, tax evasion, and antitrust violations.

The organization and emphases in the Task Force's work are illustrated in figure 2. The heavier outlines indicate the subjects of major attention. Of the methods for controlling or reducing crime, the primary focus was on the criminal justice system—the police, courts, and corrections agencies. Within the criminal justice system the greatest potential for immediate improvement by analysis and technological innovation appears to be in police operations. Hence, police problems were emphasized heavily; less attention was given the problems of courts; and still less to the inherently behavioral problems of corrections.

FIGURE 2. STRUCTURE OF THE WORK OF THE SCIENCE AND TECHNOLOGY TASK FORCE



ORGANIZATION OF REPORT

Both chapters 2 and 3 cover aspects of police operations, especially in the apprehension of criminals. The apprehension process is examined in detail with data from one city, relating apprehension to factors in the crime and in the police response to it. Since response time was found to be an important factor, various elements of the apprehension process were analyzed to find the optimum way to cut response time. In addition, specific aspects of the apprehension process are examined in some detail.

Operation of the police communications center offers an opportunity for major technological improvement so this subject is discussed in detail in chapter 3, including means of modernizing the command and control process and of relieving the radio frequency congestion characteristic of most large city police departments.

Chapter 4 deals with some aspects of court management, corrections and crime prevention. The court management discussion focuses on the problem of reducing delay in processing cases. Simulation of court operations is discussed as a means for conducting experiments and evaluating possible improvements in court procedures in order to reduce congestion.

Two aspects of corrections are reviewed in chapter 4—the use of programed instruction as an aid to rehabilitation and the use of statistical techniques to aid in making correctional decisions.

Two specific examples of how technological means may reduce opportunities for crime—auto ignition redesign and street lighting—are also discussed in chapter 4.

Chapter 5 examines the uses of systems analysis for study of the entire criminal justice system as an integrated whole. A generic model of a total system is used to calculate recidivism rates and operating costs associated with different crime control programs. This preliminary effort is limited largely by the available data, and so, more than producing solid results, identifies critical data requirements.

The potential role of modern information technology is the subject of chapter 6, in which a possible integrated information system for criminal justice is described.

Clearly, these subjects are only a sampling of the many opportunities for science and technology to contribute to the control of crime. Within the limited time, there was no attempt to address questions of the basic causes of crime, nor even to stray very far outside the criminal justice system for means of crime control. Even within the criminal justice system, many more areas need intensive study and evaluation. The subject of criminalistics, the traditional tie between technology and criminal justice, has been treated only marginally and needs specific investigation. Many fields of science and technology offer promising opportunities for exploration in addition to those covered in this brief survey, and some of these may turn out to be more significant than those covered here. Some of the other possibilities for the use of science and technology within the criminal justice system are mentioned in chapters 2 through 4.

Chapter 7 outlines a program of research and development by which the Federal Government can stimulate a major infusion of science and technology into the criminal justice process and to attack the broader problems of the control of crime.

RESULTS OF TASK FORCE WORK

From its investigations, the Task Force produced a number of preliminary results and recommendations, including:

- ☐ A compilation of field data examining certain relationships between police field operations and the apprehension of criminals.
- ☐ Procedures for improving police responsiveness to calls at minimum cost.
- ☐ An approach which could significantly reduce police radio frequency congestion.
- ☐ An outline of a research and development program for the development of a semiautomatic fingerprint recognition system to replace the present manual system under which a criminal cannot ordinarily be traced unless a full set of 10 prints is available.
- ☐ Studies examining possible technological innovations for police operations in such areas as alarm systems and nonlethal weapons.
- ☐ Statistical approaches concerned with the improvement of allocation of patrol officers in the field.
- ☐ A procedure for testing means of reducing unnecessary delays in moving cases through the courts.
- ☐ An examination of programed learning techniques as one means of contributing to the rehabilitation of young offenders.
- ☐ Methods for making auto theft more difficult.
- ☐ An exploratory attempt to apply system analysis to the overall criminal justice system.
- ☐ An outline, but not a detailed design, of a national information system for criminal justice agencies.
- ☐ A proposal for a national research and development program.

These specific results and recommendations are intended only to illustrate the potential contributions of science and technology to crime control. They must be developed in detail for each local situation and the extent of their utility must still be ascertained from better data. As illustrations, however, they appear to offer sufficient promise of the potential benefits from science and technology to warrant major efforts in these directions.

Police Operations—the Apprehension Process

Of all criminal justice agencies, the police traditionally have had the closest ties to science and technology. There is considerably more scope for the equipment technology in policing than in other parts of the criminal justice process. Police communications, transportation, weaponry, crime detection, and crime investigation all draw on science and technology to an extent that exceeds the potential in courts and corrections. Yet even here many potential contributions remain unexploited. In addition, contributions from research, information processing, and systems analysis are only just beginning to be opened. For these reasons, the Task Force focused a major part of its efforts on police operations.

The prevention or deterrence of crime is indirectly promoted by the police through such diverse means as community relations and public information programs, the selection and training of effective personnel, contingency planning for disasters or disorders, and the maintenance of an effective intelligence system.

Science and technology can improve the capabilities of the police in these areas in many different ways. The techniques of industrial psychology can aid in selecting effective police officers. Educational technology can aid in training: Programed learning texts can be used for individual study while an officer is waiting for appearance in court; closed-circuit television can be used to present skilled lecturers to a number of police precincts or departments at the same time; and simulated exercises can be used to train groups of police officers to work as an integrated team in handling unusual large-scale disturbances. The techniques of operations research can be used to allocate resources and to develop equipment maintenance and replacement schedules.

The Task Force's prime concern, however, was with what contributions science and technology could make to those police operations directly concerned with controlling crime by apprehending criminals or by deterring potential criminals with a convincing threat of apprehension. The Task Force focused on the operations of the patrol force in apprehension of individuals after they commit criminal acts. The oldest ties police field operations have to technology center around apprehension. Automobiles, radios, crime laboratories, scientific investigation, and police weaponry are all essential technical aids to the operations of a modern police force.

The apprehension process (figure 3) begins with the detection of a crime by the cruising patrol force or by a report to the police by an alarm, a witness, or a victim. Once the information is communicated to the police, an appropriate response must be selected, and patrol officers dispatched to the scene. Then follow search and investigation—interrogation, data gathering, suspect checkouts—and then, perhaps, arrest.

The choice of which technological possibilities in this area to pursue is made more difficult by the lack of data on just what situations confront the police, and by the lack of systematic studies of police patrol and apprehension operations. To try to fill this gap, the Task Force studied the factors in the apprehension process with original field data and techniques of cost-effectiveness analysis. Within the apprehension process, the functions of command-and-control and communications were found to be sufficiently important to warrant separate treatment, and are covered in chapter 3.

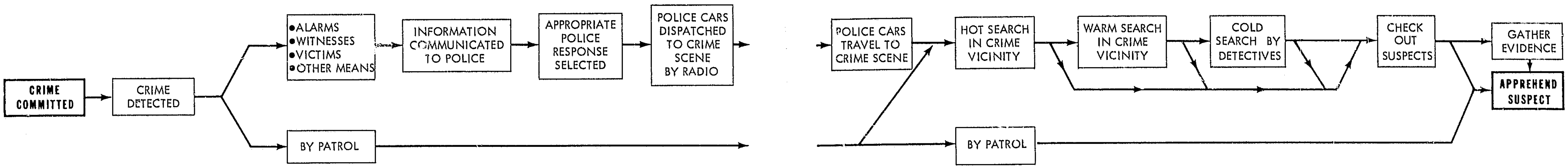
The remainder of this chapter examines the other stages in the apprehension process: detection, police mobility, nonlethal weapons, evidence gathering by fingerprints, and analysis by crime laboratories. Some of the potential scientific and technological contributions to each are identified. In addition, the problem of effective assignment of patrolmen, which overlays the entire process, is examined.

ANALYSIS OF FIELD DATA ON APPREHENSION

With the cooperation and extensive assistance of the Los Angeles Police Department (LAPD), a study was conducted to identify and assess the influence of various factors in the apprehension process on the solution of crimes. The study was an analysis of police records: Reports of calls for service, patrol field activity, crimes, detective investigations, and arrests and other case clearances were systematically analyzed. Data were collected on time delays within the communications center and response time in the field.

The sample of cases represented the total activity in 2 of 15 field divisions for the month of January 1966. The sample included 4,704 incidents, of which 1,905 actually involved reported crimes. Such police activities as arresting drunks and vagrants and handling traffic inci-

FIGURE 3. APPREHENSION PROCESS



dents were excluded. The data were collected from communication message tickets, officers' daily field reports, crime reports, detective followups, and arrest reports. The details of the study are given in appendix B.

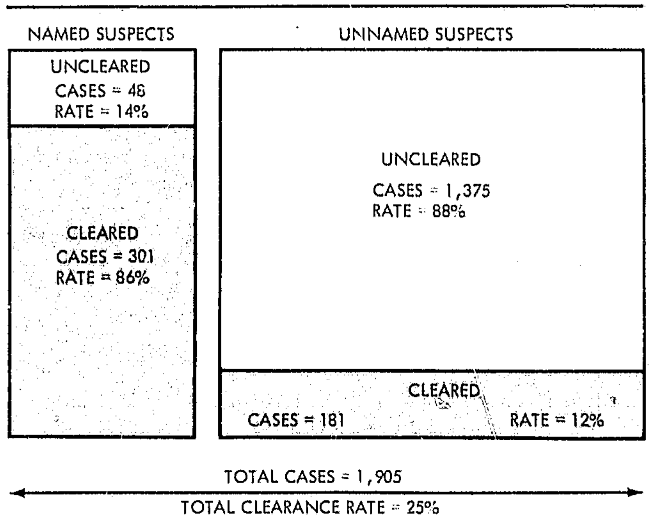
CLEARANCE OF CRIME CASES

Of the 1,905 crimes examined in the study, 25 percent (482) resulted in arrests or other clearances. Of the solved or "cleared" cases 70 percent involved arrests, and 90 percent of these were made by the patrol force. More than half the arrests were made within 8 hours of the crime, and almost two-thirds were made within the first week.

The most significant factor found to affect clearance is the naming of the suspect in the crime report.[6] As shown in figure 4, if a suspect is neither known to the victim nor arrested at the scene of the crime, the chances of ever arresting him are very slim. Of the 482 cleared cases, 63 percent involved "named suspects", about half being known by the victim and half through on-the-scene arrests (approximately 30 percent by police officers and 20 percent by store security officers). The majority of the crime cases, a total of 1,556 (82 percent), involved suspects not named in the crime report. Of these, 1,375 (88 percent) were not cleared. Even in the cleared cases with unnamed suspects, most of these were cleared because of an on-the-scene arrest, though the suspect was not "named" in the crime report. These results indicate the narrow range of situations in which apprehension is likely. They suggest a search for better means of identifying the suspect at the crime scene. One means of accomplishing that is by enabling the patrol force to respond more rapidly so as to increase the chance of actually catching the suspect at the scene.

The naming of the suspect is also an important factor in detective followup. Detectives, not surprisingly, tend to put their limited resources into cases where there is something positive to investigate. Detectives made followup reports in 363 of the 482 cleared cases. Almost two-thirds of these followups were named-suspect cases. Of the remaining third, more than half involved cases in which on-scene arrests had been made but the suspect was not named in the crime report. Of 1,423 uncleared cases, only 84 (or 6 percent) followup reports were actually made by detectives, and the suspect was identified in only 18 of these. Some followup investigation may have been made in the other cases though no reports were filed. Detectives understandably tend not to make followup reports when there is nothing to report and where there is no obvious evidence on which to base a followup investigation, no followup effort appears to be expended.

FIGURE 4. CLEARANCE OF CRIMES WITH NAMED AND UNNAMED SUSPECTS



Methods by which detectives identified suspects heavily emphasized use of stolen property and vehicle information, interrogation of arrestees, and identification by victims. Modus operandi techniques and weapon informa tion were used in only a very few cases.

[6] The "named suspect" characteristic is quite complex, however, because of ambiguity in the source data. For example, the crime report may include a named suspect because (a) the suspect is actually known to the victim (or witness); or (b) the suspect was unknown to the victim, but was arrested and identified at the scene of the crime, either by a patrol officer or by a witness such as a retail store security officer. Because the crime report was made after the arrest, the suspect's name appeared. However, this practice varies with different officers and different field situations. Thus, it is even possible to have on-scene arrests of known suspects who are not named in the crime report. These ambiguities remain to be clarified in subsequent analyses.

The study suggests considering two possible approaches to improving police effectiveness against the unnamed suspect. First, more intensive preliminary investigation at the crime scene might produce more leads for fruitful followup by detectives. Perhaps specially trained civilian investigative specialists who need not meet the physical requirements of a patrol officer could handle this job. Evaluation would be necessary to establish whether these would produce enough additional information to warrant the effort. Second, considerable detective resources are presently allocated to followup investigations in burglary cases. It is clear from the data, however, that the most effective weapon against the burglar is the on-scene arrest. The detective followup resources might be more effectively used in the field, such as in tactical detective squads or in stake-outs in heavy burglary areas. The relative effectiveness of these uses is also problematic, so such a reallocation should be carefully assessed in a controlled experiment.

RESPONSE TIME

The overall response time from call for service to arrival at the scene consists of two major components: Communications center response time (the time required in the communications center from receipt of a telephone call to transmission of a dispatching message) and field response time (the time between receipt of the dispatch message by the patrol unit and arrival at the scene).

Within the LAPD communications center, dispatch messages are divided into two general categories: emergency and nonemergency. There is an intermediate category of "nonemergency but urgent" messages which sends a patrol officer to the scene as rapidly as possible, but not using his red light and siren.

From table 1, for emergency calls, the overall police response time is seen to average 6.3 minutes for those cases involving crimes subsequently not cleared. The average is only 4.1 minutes for cases in which the police were able to make an arrest. A similar situation holds for the calls classified as nonemergency. Thus, for this city, and on the basis of this data, short response time correlates with ability to make an arrest.

Table 1.—Relation Between Response Time and Arrests

Type of call	Average response time in minutes		
	Communication center	Field response (travel time)	Total
Emergency:			
Crime uncleared	1.9	4.4	6.3
Arrest made	1.1	3.0	4.1
Nonemergency but urgent:			
Crime uncleared	3.8	[1] 4.0	7.8
Arrest made	2.6	2.7	5.3
All other nonemergency:			
Crime uncleared	7.3	[1] 12.9	[2] 20.2
Arrest made	5.6	4.6	10.2

[1] Very small sample.
[2] Reflects high proportion of calls merely to take a report on completed crimes.

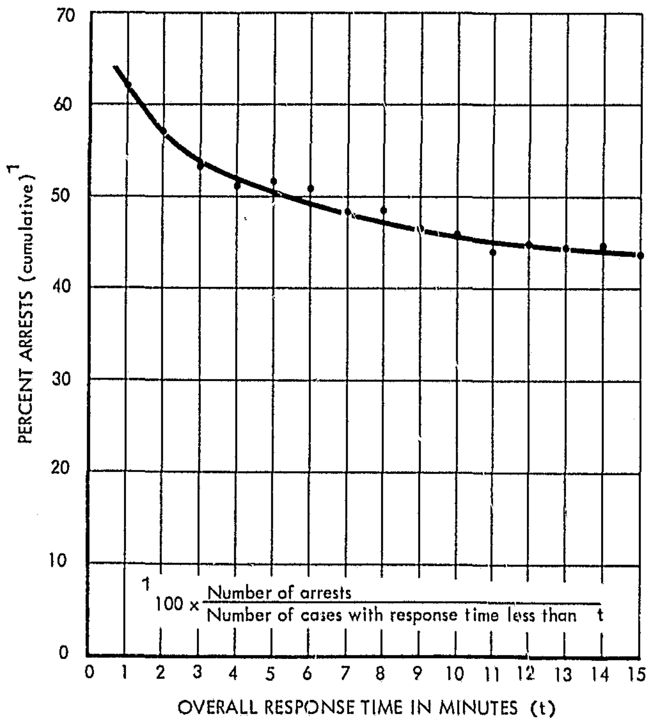
A similar picture is presented in figure 5, which shows the arrest probability as a function of response time. When response time was 1 minute, 62 percent of the cases ended in arrest. When all cases with response time under 14 minutes were grouped together, only 44 percent led to arrest.

To this point, arrest probability has only been shown to be correlated with response time. As in any correlation, the relationship may be one of cause and effect, or it may have developed through some uncontrolled third factor to which both arrest and response time are related. It is possible, for example, that the police force responded more rapidly to those incidents in which arrest was recognized to be more probable. More carefully controlled tests than were possible in the time available are needed to establish a cause-and-effect relationship definitively.

CRITERIA FOR EMERGENCY DISPATCHING

Another factor which appears to affect patrol operations significantly is the method for deciding whether a

FIGURE 5. PERCENT OF ARRESTS IN RELATION TO OVERALL RESPONSE TIME



call should be handled as an emergency. Of the 724 emergency calls shown in table 2, 179 (or 25 percent) proved to be crimes,[7] and 63 of these (or 35 percent) were cleared. On the other hand, 3,378 nonemergency calls were handled with no indication of urgency. Of these, 1,368 (or 40 percent) involved crimes, of which only 230 (or 17 percent) were cleared; most of these calls were requests to make a report on a completed crime.

Of the 1,138 nonemergency uncleared crime calls, 112 (or 10 percent) actually involved "suspect on scene" or "possible crime" situations which later proved to be crimes. These 112 cases equal almost two-thirds the number of emergency-call crimes, and nearly twice the number of emergency calls in which crimes were cleared. Among these 112 cases are a significant number of burglaries and robberies. Even one homicide was listed. At least 50 of these cases would have been handled as emergencies had the dispatcher known the actual situation at the scene.

Table 2.—Results of Radio Calls

	Emergency calls	Nonemergency but urgent calls	Nonemergency calls	Total calls
Radio calls	724	274	3,378	4,376
Percent of total calls	17	6	77	100
Radio calls with crimes reported	179	67	1,368	1,614
Percent of radio calls	25	24	40	37
Uncleared crimes	116	38	1,138	1,292
Percent of crimes	65	57	83	80
Arrests made	53	23	151	227
Percent of crimes	30	34	11	14
Other clearances	10	6	79	95
Percent of crimes	5	9	6	6

This strongly suggests that some improvement in crime prevention and clearance could be expected from modifying the criteria for assigning priority to dispatch orders or from providing better information to the dispatcher. A specific research program should be undertaken to evaluate and design new procedures. This program would evaluate the present priority assignment criteria through a detailed examination of incoming calls for service and associated field response. An audit of the results of responses to calls could guide improvement of the criteria, and these could then be reevaluated through the same methods employed in the initial evaluation.

FURTHER STUDIES

This apprehension study is only one of many possibilities. The entire Los Angeles study was only preliminary and exploratory. Its results, however, suggest that significant improvements can be made in the early stages of the apprehension process. Similar studies running over several years should be undertaken in large metropolitan police departments to explore the detailed characteristics of crimes, arrests, and field investigation practices.

Among the matters to be studied, as shown by the Los Angeles study, are:

Assessing in more detail the effects of response time on arrests.

Estimating the probability of clearing a crime as a function of type and quantity of detective resources assigned to it.

Establishing criteria for priority of dispatching of patrol cars.

Sampling incoming calls and following them through to activities in the field.

Using equipment such as portable recording devices to simplify data collection by the investigating officer.

This kind of factual study could also be extremely valuable in determining the effects on later stages in the criminal process of the questioning of suspects, warning them as to their rights, and introducing counsel into the situation.

SYSTEMS ANALYSIS OF RESPONSE TIME IN A HYPOTHETICAL CITY

On the basis of the correlation between response time and arrests, and because officials desire rapid response to

[7] Many of the emergency calls were false burglar alarms.

create an impression of effective police presence as well as to aid in apprehension, the Task Force examined means of reducing response time. In particular, an analysis was conducted to determine how to get the greatest reduction in response time per dollar of cost.[8] This analysis was accomplished by making a mathematical model of the apprehension process in a hypothetical city. Although the numerical values used in this example are based on averages from several large cities, they typify a generalized major city in the United States. Any specific police department would have to develop and use data developed for its own city.

The hypothetical city covers 100 square miles and has a police force, telephone system, and other variables shown in table 3. A city this size would have a population of about 500,000 and be comparable in population density to Atlanta or Indianapolis.

In the analysis, time delays in the apprehension process were related to system resources (table 4), and costs were associated with each resource. The analysis computes the time reduction and costs associated with various means of reducing response time. The improvements were measured in average number of seconds of delay saved per dollar of additional annual cost.

Table 3.—Description of Hypothetical City

Item	Details
Geography	The city is a 10- by 10-mile square.
Rate of call receipt [1]	40 calls per hour or approximately 350,000 calls per year are handled by the police telephone complaint clerks.
Rate of police mobile unit dispatch	30 one-man mobile units are dispatched per hour.
Total mobile force [2]	40 one-man patrol cars.
Speed of mobile force	25 m.p.h.
Public telephone distribution	1,000 distributed uniformly throughout city.
Call service time	30 minutes average
Number of call complaint clerks	2 or 3.

[1] This might be typical for a city of about 500,000 population.
[2] Considers only mobile units assigned to patrol functions independent of special detective forces and supervisory vehicles.

Table 4.—Resources Associated With Time Delays in the Apprehension Process

Components of response time	Resources
Time until detection	Police patrol unit sensors, alarms, public's response.
Time from detection until attempt is made to transmit message to police.	Police callboxes, police radio network, common carrier telephone, automatic alarm and associated communications.
Incoming message queue waiting time.	Telephone operators.
Control center response time	Police control center internal operations.
Field force response time	Patrol unit, car-location devices.

The results of the analysis are summarized in table 5. In the first column the delays caused by each activity are identified. For example, the patrol mobility delay is the time from the termination of the dispatch order to arrival at the scene of the crime. The basic operating unit associated with this activity is a one-man patrol car (col. 2). There are 40 such units already in use (col. 3). The amount of this delay is 216 seconds (col. 4). If one additional unit were added the average response time would decrease by 4 seconds (col. 5). The patrol units are expected to be used 264,000 times a year (col. 6). The cost of an additional unit is $50,000 per year (col. 7). Multiplying the delay saved per call per additional unit (col. 5) by the frequency of use (col. 6) and dividing by the cost of the additional unit (col. 7), one obtains 21.1 seconds saved per dollar (col. 8).

Employing this technique, one can evaluate the changes in other components such as the complaint clerk, public callbox, automatic car locator, and computer and collateral equipment for the communications center. For this case, automating the command center is the most attractive alternative. If there are only two complaint clerks, adding a third is the next most desirable step. Even though the telephone queue waiting time with two clerks is only 7.2 seconds the value in assigning a third complaint clerk is comparatively large. The low cost of the clerk and the high frequency with which he becomes involved in calls justifies such a move. As is shown in table 5, adding a fourth would not be desirable.

Table 5.—Cost-Effectiveness Analysis of Delay Reduction in Hypothetical City

Elements of delay (1)	Basic unit (2)	Number of units currently allocated (3)	Delay time (seconds) (4)	Seconds of delay saved per call per additional unit installed (5)	Frequency of use (calls/year) (6)	Cost per year of additional unit (7)	Seconds of delay saved per dollar allocated (8)
Public access delay	Public callbox	1,000	96	0.0475	10,000	$50	9.5
Telephone queue waiting time	Complaint clerks	2 3	7.2 .042	7.158 .042	350,400 350,400	35,000 35,000	71.7 .42
Delay due to lack of command and control function automation.	Computer and related hardware for command and control center.	0	120	90	264,000	200,000	119
Delay due to lack of knowledge of exact position of patrol unit.	Automatic car locator system	0	20	18	264,000	100,000	47.5
Patrol mobility delay	1-man patrol car	40	216	4	264,000	50,000	21.1

[8] The details of the analysis are in a separate paper, "Analyses of the Police Apprehension Process," now in preparation. The report will be available from the Clearinghouse for Federal Scientific and Technical Information of the National Bureau of Standards.

The third most significant contribution lies in the installation of an automatic car-locator system. For the city described, an average of 18 seconds delay can be directly attributed to choosing an available car other than the one closest to the disturbance. Even though a small portion of the overall delay time is reduced, the marginal returns are relatively high.

Among the conclusions about the hypothetical city that may be drawn from detailed analysis of the sort illustrated are:

> The police command and control center appears to be the best place to invest dollars to decrease response time.
>
> Automatic car-locator systems costing under $100,000 per year to operate would decrease the system delay at least twice as much as a comparable investment in additional patrol units.
>
> Since telephone waiting time is very sensitive to load, an additional complaint clerk would be warranted in many situations where the clerks are now busy. Police departments should periodically perform a telephone-traffic study of their incoming calls to determine the correct number of telephone complaint-clerks for assignment at any given time.
>
> Since the hypothetical city already has public callboxes, the incremental value of additional ones would be low. Cities with locked callboxes should open them and encourage the public to use them.

These results apply directly only to the hypothetical city described previously. The analyses discussed here suggest similar ones that can and should be conducted in specific cities.

IMPROVING APPREHENSION CAPABILITIES

In this section, several specific components of the apprehension process—alarms, detection and surveillance devices, nonlethal weapons, vehicles, fingerprint identification and crime laboratories—are discussed.

DETECTION OF CRIMES

The apprehension process is initiated by the detection of a crime by police on patrol, by a witness, by a victim, or else automatically by an alarm or surveillance device.

Patrol Detection

Police on "preventive patrol" cruise the streets to look for crimes in progress. Presumably, this activity prevents crime because it poses a threat of detection and immediate apprehension. However, there is little evidence on how much crime is thereby prevented or on how much would be prevented with alternative patrol tactics.

One can calculate the probability of detecting a crime as a function of the relevant variables: duration and visibility of the crime, the frequency with which it occurs, the cruising speed of the patrol vehicle, the fraction of time it spends on patrol, and the size of the beat it must cover. Making certain assumptions about the duration of crime (2 minutes for a street robbery and 20 minutes for a burglary) and that crime and patrol locations are independent, one can calculate the detection chances. Using Los Angeles figures,[9] in a week the entire force happens upon at most 100 opportunities to detect burglaries in progress and 2 opportunities to detect street robberies in progress. These are high estimates, yet they represent only 12 percent of the burglaries and only 2 percent of the robberies known to the police. An individual patrol officer can expect an opportunity to detect a burglary no more often than once every 3 months and a robbery no more often than once every 14 years.

The same analysis applied to stolen cars indicates that the entire force experiences approximately 100 opportunities to detect stolen cars each day. There would, therefore, be considerable utility in mechanized automobile license check devices, either in the patrol car or along the highway. Digital data links could tie a patrol car directly into the stolen-car file in a computer; the computer response could be available seconds later, displayed on a strip printer in the car or as a voice message synthesized by the computer. The New York State Identification System has begun development of a device which could scan a car's license plate and automatically convert the image into a message to be sent to an on-line computer with a file of wanted cars. The computer could then respond directly by radio to a waiting patrol car. In a test of these concepts in Operation Corral in New York City in 1964, 183,950 cars were checked, and one out of every 62 cars scanned was wanted on an alarm for stolen cars or plates or on a warrant as a scofflaw.

There are many simple ways to increase the probability of detection of a crime. Liquor stores and service stations could provide an unobstructed view of the interior from the street. The visibility from the patrol car could be improved by full-view mirrors. Brighter and more prevalent street lights could extend the patrolman's vision, especially in large, normally dark areas such as schools and other targets of vandalism.

Reducing the conspicuousness of police officers could possibly increase the probability of detecting criminal action because the offender is not aware of the police presence. In some cities, special forces travel in work clothes in unmarked cars. The Long Beach, Calif., Police Department sends two plainclothesmen on bicycles into high crime areas. According to the "New York Times:"[10] "No screaming sirens or flashing lights announce them. They operate inconspicuously, silently, independently and with mobility up sidewalks, between buildings, or through parks." In 1 year, the two policemen made arrests in eight strong-arm robberies, five armed robberies, eight burglaries. Street crimes were reported to have been reduced markedly supporting the general assumption that increasing the apprehension probability tends to deter crime, or at least to displace it. On the other hand, were such inconspicuous methods to be used alone, they might, after some time result in some loss of the deterrence and public confidence that are achieved by conspicuous patrol. Again, this illustrates the need to examine the relationship between detection, apprehension, and deterrence with carefully controlled experimentation.

Detection by Alarms and Surveillance Devices

There is a rich store of devices which can aid detection. Burglar alarms are designed to detect intrusion automatically. Robbery alarms enable a victim of a robbery or an attack to signal for help. Such devices can be located in elevators, hallways, homes and apartments, businesses and factories, and subways, as well as on the street in high-crime areas. Alarms could deter some potential criminals from attacking targets so protected. If alarms were prevalent and not visible, then they might serve to suppress crime generally, although there has been no empirical evidence on this point. In addition, of course, the alarms can summon the police when they are needed.

All alarms must perform three functions: sensing or initiation of the signal, transmission of the signal, and annunciation of the alarm. A burglar alarm needs a sensor to detect human presence or activity in an unoccupied enclosed area like a building or a room. A robbery victim would initiate the alarm by closing a foot or wall switch, or by triggering a portable transmitter which would send the alarm signal to a remote receiver. The signal can sound locally as a loud noise to frighten away a criminal, or it can be sent silently by wire to a central point such as a police station or a private protection agency. A centralized annunciator requires either private lines from each alarmed point, or the transmission of some information on the location of the signal.

There are many ways by which burglary sensors can detect human presence or activity. Certain environmental variables could be carefully stabilized so that any sudden change—breaking a beam like an "electric eye," moving metal objects in the vicinity of a magnetometer, making a sharp noise, cutting a wire, stepping on a treadle—could be attributed to intrusion. Any change in the physical or chemical environment due to characteristically human effects—carbon dioxide, ammonia, body odors, body heat—could be detected chemically, electrically, or by animals such as dogs. Other sensors such as closed-circuit TV (perhaps using circuitry for detecting moving targets) or microphones might survey an area, relying on an observer to analyze the signal for criminal activity. These would be more useful where there is normally some human traffic, and a more subtle discrimination between criminal and noncriminal traffic is needed.

A victim could activate a robbery alarm by closing an electrical circuit by a pull lever, a push button, a toggle switch, or a pull-cord like the ones used in buses. Since a robber can prevent access to such a fixed switch, a potential victim could be given a portable transmitter which he could unobtrusively trigger to send a magnetic, radio, or ultrasonic signal to a remote receiver nearby. The transmitter could be powered by a battery, by blowing, by squeezing, by a carbon-dioxide cartridge, by a spring, or by some other simple energy storage medium. Such a portable system would be particularly appropriate in places most susceptible to robbery like gas stations, banks, or liquor stores.

In choosing one alarm system over another, cost, local noise characteristics, detection probability, rate of false alarms by accident or intent, penetration of signals through walls, visibility to a potential criminal, accessibility to a victim, and many other factors specific to a local situation influence the choice. No one solution can meet the many diverse needs. Where such systems are installed their apprehension and deterrent effectiveness and their false-alarm rates should be assessed.

The possibility of installing along the streets microphones sensitive only to a designated call such as "Help" or "Mayday" is sometimes discussed. The complexity and cost of such a system, compounded by the problem of false alarms, militate against its widespread use.

The installation costs of public street alarm systems might not be unreasonable. Suppose that fixed alarm points were located 40 to the mile (at the corners and midpoints of each city block) in a high-crime area. The maximum distance to the nearest alarm point would be about $1/80$th of a mile. Walking this distance at 4 miles per hour would take 11 seconds. The time for a police car to reach the scene would probably be several minutes so that the walking delay would not consume a major portion of the time. If each fixed alarm cost $250, covering a square mile of city would cost about $400,000 per square mile, plus approximately $800 per square mile per month for rental of wire lines. The cost could be reduced by sharing the wire costs among alarms (and losing precision in locating the alarm), or by increasing the spacing between alarms. Doubling the distance (one at every intersection) would reduce the investment cost to about $100,000 per square mile. For those cities that have police callboxes a major cost of installation has already been incurred.

A portable street alarm system, using a $1,200 receiver at each intersection, would cost about $480,000 per square mile, plus about $200 per square mile per month for wire rental connecting the receivers to a central station. The cost of the individual transmitters would be additional.

If the city had some form of distributed receivers, such as in the callbox car-locator system discussed in the next chapter, then those receivers might be modified to respond also to pedestrians' transmitters or to transmitters installed in taxicabs or automobiles. If the availability of such a system could induce a feeling of safety in high-crime areas, they might increase the pedestrian traffic there, which itself might be a deterrent. Just how much they would or could actually be used, how effective they are in apprehension, how much they would deter crime, how criminals might frustrate their use, and what false alarm problems they might entail are all unknown. Since these

[9] Data from "Statistical Digest, 1965"; Los Angeles Police Department; Los Angeles, Calif., 1966.

[10] "A Bicycle Patrol Cuts Crime," New York Times, Oct. 25, 1966.

factors are crucial in assessing the feasibility of such systems, a test installation should be established in some high-crime area to assess some of these effects.

False alarms are problems for any alarm system. In Washington, D.C., in 1965, 4,450 alarms were directed to the police: 98 percent of these were false. Since answering each false alarm takes an average of about 30 minutes, these alarms consume about 2,100 car-hours each year, the equivalent of about one-quarter of a full-time patrol car. However, in those cases where the alarm is for an actual crime, the apprehension probability could be very high,[11] so that the assignment of high priority service to all alarm soundings is probably an efficient allocation of resources.

New low-cost private alarm systems that can automatically send prerecorded messages directly to the police are being developed and may become widely installed. As a consequence, the police should expect a significant increase in the number of false alarms. To prevent this increase from seriously disrupting police operations, police departments should establish minimum standards for direct-calling alarm installations. On-site inspection should be required to assure that the alarm itself is mechanically and electrically reliable (usually not a serious problem), that its installation is not subject to simple accidental failure (as from a blowing wind), and that it is not subject to accidental triggering by the occupants. The false-alarm rate can be reduced by means such as using two different detection sensors, increasing the sensitivity of each, and requiring simultaneous triggering of both to establish an alarm.

POLICE VEHICLES

Once a crime is detected, the information concerning it is communicated to the police, the appropriate police response is selected, and orders are communicated to the patrol force. Travel time in reaching the crime scene is the largest single component of police response time. While the patrol car will undoubtedly continue as the primary police vehicle, the more specialized roles of other kinds of vehicles need further exploration. Many cities are now using motor scooters or bicycles to give their foot patrolmen added mobility. At the other extreme, helicopters offer a potential for demonstrating a police presence, for searching a large patrol area and for responding rapidly (over 100 miles per hour) to an emergency call when the action is taking place in the streets, on rooftops, or on highways.[12] Their potential has not yet been adequately explored.

Despite the other possibilities, the conventional patrol car will continue to dominate the police scene. For the patrol officer, it serves as his office, means of locomotion and pursuit, observation post, and van for transporting prisoners. Most police cars are merely stock sedans, with a flashing light and radio installed, and perhaps with a modified engine. Since it costs about $100,000 per year to maintain a two-man car on continuous patrol,[13] it would be surprising if the operation could not be appreciably improved by a capital investment of more than the current $3,000 per car.

The Federal Government should sponsor a design competition and support the development of an experimental police car. It could incorporate a wide variety of practical innovations, such as convenient radio controls, teletypewriter, camera and equipment for collecting evidence, various nonlethal weapons, magnetometers for detecting the presence of concealed weapons, spotlights, mirrors and other viewing devices to improve visibility, and dictating equipment for filing of reports and recording confessions. Continual use of the radio and frequent necessity for written record-keeping suggest a rearrangement of the interior to facilitate these functions. Development of the new design should include human factor considerations derived from a study of the patrol operation. Such a car would provide a useful prototype for testing new equipment, and would stimulate police departments to reconsider how they might use their vehicles.

NONLETHAL WEAPONS [13a]

A patrol officer, in meeting the diverse criminal situations he must face, has a limited range of weaponry—either the short-range nightstick or the potentially lethal handgun. He should have other possibilities to help him do his job while minimizing the danger of excessive injury or public antagonism. If an officer feels that his life is threatened, he may have to shoot, with the attendant risk that suspects or bystanders may be killed. In many situations, however, he may not be in immediate mortal danger, but his nightstick may be inadequate, either because the target is out of range, there are too many people to handle, or it may inflict more severe injury than the situation warrants. Relevant situations involving one or a few officers include:

Apprehending a fleeing suspect.

Apprehending an individual in a closed building.

Subduing a belligerent person under the influence of alcohol.

Restraining a psychotic intent upon attacking bystanders or upon self-destruction.

A larger group of officers may be confronted with a number of people who must be controlled, channelized, or dispersed, as in the case of public riots, prison riots and gang rumbles. If a suitable range of graduated alternatives were available, and if there is time for weapon selection, then officers could use the weapons most appropriate to the situation.

For a nonlethal weapon to be an acceptable replacement for a handgun, it must incapacitate its victim at least as fast as a gun. Even then there might be opposition to it. A criminal knowing that he cannot be killed might act more aggresively than he would facing a gun. The qualities that must be sought in a general purpose nonlethal weapon are almost immediate incapacitation and little risk of permanent injury to the individual who is the target. It must also meet size, weight, and other

[11] In the Los Angeles apprehension study, there were 24 actual burglaries reported by alarms. Seven arrests were made by the responding patrol. This clearance rate is twice as high as for the other burglaries in the sample.

[12] The Los Angeles County Sheriff's Office, with the support of the Office of Law Enforcement Assistance, is now evaluating the patrol effectiveness of helicopters.

[13] Considering vacations, sick time, etc., it takes about 10 patrolman-years to maintain a 2-man car on continuous patrol. One patrolman-year, including overhead, costs in the order of $10,000.

[13a] This material is covered more completely in a report, "Nonlethal Weapons for Use by United States Law Enforcement Officers," now in preparation. The report will be available from the Clearinghouse for Federal Scientific and Technical Information of the National Bureau of Standards.

operational standards. Survey of a wide range of possibilities leads to the conclusion that these requirements cannot be met by current technology. For example, darts have been used to inject tranquilizing drugs into animals. However, the drugs presently available offer too great a risk because of the close correspondence between the dose required to incapacitate quickly and a lethal dose. No nonlethal weapon is presently available that could serve as a replacement for the handgun, but a continuing effort to achieve such a weapon should be pursued. In this connection the products of military research should be continually examined for possible applicability.

When a nonlethal weapon is considered as a supplement to, rather than replacement for, the policeman's gun, the requirements for immediate incapacitation can be relaxed. Supplemental nonlethal weapons, such as dispensers of tear gas or CS gas or liquid solutions, might be used temporarily to disrupt or immobilize targets in circumstances in which an officer's life was not threatened.

A number of nonlethal weapon possibilities are listed in table 6 together with their intended physical effects (the effects which can be expected to follow from their proper use under anticipated conditions) and their potential physical hazards (more serious effects which might result from improper use or from proper use under unanticipated conditions). The list is presented to indicate the range of possibilities that have been proposed by various people, and not to indicate that all or even most are desirable for use in any particular situation. For most of these devices, for instance, there is no evidence to determine whether the intended physical effects, even when achieved, result in a desired behavioral response.

With few exceptions, all techniques must be recognized as presenting at least some secondary, if not primary, risks to health and safety. In addition, some of the techniques without major risks, such as the electric prod, can be personally degrading, and even their use in noncriminal situations must be carefully considered. Others, such as dogs, may have become sufficiently inflammatory symbols in certain mob situations as to warrant careful consideration of their use despite their general effectiveness.

Some of the ejector weapons listed in table 6 can be employed with any of a number of different encapsulated solid, liquid or gaseous nonlethal agents. The effects and hazards of such weapons (such as dart guns) depends on the specific agent used rather than the weapon itself. A few such agents are listed in table 7 together with their intended physical effects and potential physical hazards.

Tables 6 and 7 include devices and materials that are not properly "weapons" in the narrow sense, but which may be useful for marking people or vehicles (dyes, odorants) for later identification and apprehension.

As is evident from tables 6 and 7, a broad spectrum of different effects can be achieved. Certain difficulties are encountered, however, when a weapon is sought which will achieve its intended effects within a couple of seconds or with minimal potential hazards. For example, onset time of injected agents depends upon transit time through

Table 6.—Some Possible Nonlethal Weapons

Nonlethal weapon	Intended physical effects	Potential physical hazards
Gun aimed at nonvital area	Immediate partial incapacitation	Permanent injury or death.
Baton	Partial immobilization and injury	Excessive injury.
Dogs	Partial immobilization	Lacerations.
Water hose	Knocking victim down	Injury resulting from fall.
Electric prods	Shock inducing desired movement	Minor.
Nontoxic smoke	Disruption of vision	Minor.
Stench bomb	Extreme olfactory discomfort inducing departure from area	Minor.
Particle projector (e.g., shotgun)	Trauma from impact	Serious or lethal wounds.
Injector dart gun	Incapacitating agent injected	Wounds, death or serious illness due to overdose; impact on sensitive or vital area; infection.
Liquid ejector (e.g., pistol, baton)	Incapacitating agent applied externally to eyes or respiratory system	Depends on toxicity of agent.
Splatter dart gun	Liquid incapacitating agent applied externally	Depends on toxicity of agent.
Gas dispenser	Incapacitating agent inspired	Depends on toxicity of agent.
Gas dart gun	Gaseous incapacitating agent inspired	Depends on toxicity of agent.

Table 7.—Some Possible Agents for Nonlethal Weapons

Nonlethal agent	Means of delivery	Physical effects intended	Potential physical hazards
CN (tear gas) (α chloracetophenone).	Gun or bomb	Induces tearing (disrupting vision), itching of skin within seconds.	Minor.
CN (solution)	Liquid ejector	Same as CN (tear gas)	Minor.
CS	Gun or bomb	Induces within 20–60 seconds tearing, itching, coughing, respiratory distress, stinging on moist skin (e.g., lips), sinus irritation (effects on vision last for about 10 minutes).	Eye damage if rubbed when under effect of CS; nausea and vomiting if CS injested.
Tranquilizer	Injector dart	Relaxation or immobilization	Serious illness due to overdose (since dosage depends on body weight, etc.).
Organic Acids (e.g., formic, lactic, acetic).	do	Induces extreme pain within seconds followed by analgesia for 10 to 20 minutes.	Serious illness due to overdose.
Odorants	Splatter dart	Marked for later identification	Minor.
Nontoxic dyes	Splatter dart or spray	do	Minor.

the bloodstream, which is much slower than transmission through the nervous system. Injected agents would usually be deposited immediately under the skin or in the muscle. (The possibility of direct depositing in a vein or artery is remote.) Thus, the time for absorption and distribution of the agent could be expected to be on the order of 15 minutes or more.

Some agents are potentially hazardous because the minimum strength required to incapacitate a large, healthy man may exceed the danger threshold for others such as women, children, older people, and people in marginal health. In order to minimize this problem, it is necessary to search for agents for which the ratio of hazardous to effective dose is sufficiently high to assure safety. Another complication is that the safety factor is generally decreased as the chemical agent is modified so as to speed up the onset of its effects. Thus, while no adequate agents are available today, the results of military research should be carefully followed, both to identify potentially useful agents and to assess their effects.

Selecting weapons for further development or procurement requires adequate information on their operational effectiveness and hazards. The data must include the effects on the intended targets, the effect in influencing behavior under different circumstances, and the general reaction of the public to use of the technique. The evaluation must include both situations in which the weapons were used effectively and ones in which they failed in their purpose. There should be centralized reporting of the direct effects, desirable and undesirable side effects, and the behavioral response of the specific targets and the general public. This is especially important in situations when weapons are used to control crowds. An independent organization should be assigned the responsibility of collecting, collating, and disseminating analyses of such reports.

When additional weapons are distributed to a police force, guidelines controlling their use should be carefully established. These reviews are particularly necessary, since the introduction of less harmful weapons makes their use in marginal situations more likely. The guidance of all responsible segments of the community should be sought in establishing the guidelines. With the rapid expansion of the range of nonlethal weapon possibilities, these issues must be constantly reviewed with respect to both old and new weapons.

IDENTIFICATION

Evidence found at and near the scene of the crime must be collected and analyzed to solve crimes for which no suspect is identified. Witnesses can describe the criminal's appearance, the modus operandi can be inferred, and physical evidence such as latent fingerprints, blood, articles of clothing, bullets, and tool marks, can be collected and matched to suspects and their possessions. This information search organizes the evidence to eliminate the maximum number of people from the class of possible suspects.

Fingerprint Identification

Effective police work uses fingerprint identification both to apprehend those who leave "latent" prints at the scene of a crime and to identify positively persons held in custody.

Positive identification of persons already held makes use of files set up according to a 10-print classification system, since all 10 prints can be obtained from such persons. Manual techniques of 10-print classification and search have been used for more than 50 years. The major limitation in their use is the time it takes to search the files due to the large number of prints in modern files—the FBI file now contains over 16 million sets of different criminal prints plus about 62 million different civil service and military prints. The classification and search problem is compounded by the large volume of prints which must be processed—each day the FBI receives about 30,000 sets for processing, of which approximately 10,000 are based on arrest. Advances are needed to increase the workload capacity and to reduce the costs and time delays of the fingerprint classification and search processes.

In order to search the regular fingerprint files using the classification formula now in use, a full set of 10 fingerprints is needed. When a criminal inadvertently leaves fingerprints at a crime, only one or a few fingerprints are usually available to law enforcement officers. Once a suspect has been taken into custody, his fingerprints can be compared with even a single print recovered from the scene of the crime. By the same token, a single print can be matched against complete prints of a short list of likely suspects. But the process is now entirely manual and so time-consuming that it cannot be used to check less than a full set of prints against a national file or even a substantial local file of previous offenders. As a result, single print files tend to be very small, generally containing only a few thousand prints (compared to millions in the larger 10-print files) and are very infrequently used.[14] Most large police departments maintain a specially organized file of single fingerprints of several thousand persistent criminals. Probably more than 100 different manual systems are in use today for searching files of single fingerprints of persons who have been judged likely to violate the law persistently. Comparison of their relative performance might provide a valuable guide in developing future systems.

Computer technology can significantly enhance fingerprint processing. However, the problem of reading from fingerprint cards or films using present-day techniques and then categorizing the fingerprints completely automatically exceeds present technology. Pattern recognition has been a difficult field and the type of pattern recognition called for in processing fingerprint data is particularly difficult. The problem is made even more difficult by the smudges and missing ridges on inked prints. While computers are expected to be of significant assistance in locating key points, making measurements, assigning descriptors, and comparing new prints against a stored file, it

[14] The New York City Police Department has a sizable latent print file. They report an 8 percent success rate on searches of that file; this is about an order of magnitude higher than most other agencies' reports.

does not appear feasible at this time to make the system completely automatic.

It appears that an initial system should be semiautomatic—a trained operator working in conjunction with electronic scanners and computers. Trained technicians would be used to scan the prints either in their present form or by means of some pictorial display and to classify the gross patterns, probably to locate such critical points in a print as the core and delta, and perhaps to identify and locate such minutiae as ridge endings and bifurcations. These approaches are discussed in appendix C.

Latent-print identification is more difficult than 10-print identification because of the smaller amount of information available in less than a full set of prints. The New York State Identification and Intelligence System reports that, given two fingerprints both from the right hand, one of the index finger with an ulnar loop and a ridge count of 9, and the other of the right middle finger with an ulnar loop and a ridge count of 12, 45,000 candidate prints (4.5 percent) would be selected from a file of 1 million 10-print cards. If only the right middle finger was obtained, 370,000 prints (37 percent) would be selected from the file. Clearly, such gross classification is inadequate for even a 10-print search. The information for single print search is available in a fingerprint. It is necessary to develop classification schemes that use it.

It is difficult today to measure accurately the benefits of a latent search capability. If most burglaries were performed by juveniles whose fingerprints are not on file, or if an effective system led most burglars to wear gloves, then its benefits would be minimal. On the other hand, if it could contribute to raising the very low clearance rate of burglars not caught in the act, then it might have a significant deterrent effect on this most common Index crime. A utility study in one or two police departments is needed to assess how many more arrests might be made with a latent fingerprint capability.

Some preliminary indications of the utility were provided by the Los Angeles apprehension data (appendix B). A "technical specialist", usually a fingerprint technician, was requested to visit the scene of the crime in more than 40 percent of the 626 burglaries in the study sample. Each request was made because a patrol officer suspected the presence of fingerprints. No information was recorded on whether the specialist actually arrived at the scene; in fact, there is some reason to believe that due to lack of staff, the requested specialist often did not arrive. Yet, of the 269 cases in which the technical specialist was contacted, 28 cases actually produced fingerprint evidence. This is equivalent to about 5 percent of all burglaries in Los Angeles, or at least 2,500 cases per year where fingerprint evidence would be expected.

These indications suggest the value of undertaking the basic work to improve the efficiency of 10-print classification and to make latent-print identification feasible. Information is needed on the statistical distribution of fingerprints according to the various criteria now being considered. The study should investigate the distribution within categories (for instance, the variations in ridge counts from core to delta for ulnar loops or the frequency characteristics of the two-dimensional Fourier transform of the print) and ultimately should establish a search procedure based on the data gathered. Since actual statistics will be required on fingerprint characteristics in order to evaluate classification techniques, a small model of an actual system should be put into operation in order to obtain the necessary data.

The studies should be coordinated among the State and Federal agencies involved. Although the emphasis may be different—the FBI is concerned with efficient processing in its large identification file, while States and cities may be more concerned with improving latent-print matching—efforts in the two directions may complement each other. The New York State Identification and Intelligence System has already initiated work in this area, the FBI has collected proposals from industry, and several companies have invested modest amounts of money in research efforts. The present level of support is almost certainly below a critical threshold, so additional government support should be committed.

Personal Identification by Physical Features

Techniques for arriving at standardized classifications of physical characteristics other than fingerprints have long been used in police work.

Perpetrators of a crime are often described by witnesses or victims in terms of salient facial features. The Bertillon System which preceded the widespread use of fingerprints was based on body measurements. Recently there have been developments in the quantification of classification and comparison procedures for facial characteristics. Devices[15] are now available which enable a trained operator, with the aid of a witness, to form a composite picture of a suspect's face and to translate that composite into a numerical code. Testing is needed to ascertain the reliability of each of these techniques. For those which are reliable, further developments are possible, using computers to develop efficient sequences of questions to witnesses to converge quickly to the proper description.

Recent studies of voice analysis and synthesis, originally motivated by problems of efficient telephone transmission, have led to the development of the audio-frequency profile or "voice print." Each voice print may be sufficiently unique to permit developing a unique classification system and perhaps even to make positive identification of the source of a voice print. This method of identification, using an expert to identify the voice patterns has been introduced in more than 40 cases by 15 different police departments. As with all identification systems that rely on experts to perform the identification, controlled laboratory tests are needed to establish with care the relative frequency of errors of omission and commission by the experts.

Analysis of Physical Evidence in Crime Laboratories

The crime laboratory has been the oldest and strongest link between science and technology and criminal justice.

[15] MIMIC, Identi-Kit, New York City's Image Maker.

Because of this tradition, and because the best laboratories, such as the FBI's, are well advanced, the Science and Technology Task Force did not devote major attention to criminalistics. There are some excellent laboratories in key locations around the country. However, the great majority of police department laboratories have only minimal equipment and lack highly skilled personnel.

Traditional efforts of crime laboratory specialists have been directed toward the identification of materials found at the crime scene. Many instruments have been constructed which enable specialists to determine the chemical structure of various substances. Particularly important are analyses of drugs, paints, fibers, oils, and human hair and blood. In the classification and comparison process, it is not necessary to know the exact chemical composition of the material, but only how it compares to a known standard, such as a known drug, or another part of the same object, such as a paint chip. When it is necessary to know of the presence of a particular chemical element, often it is the minor or trace elements which are of interest, not the major elements.

The instrumentation industry is constantly devising new ways to measure smaller samples with greater precision. Unfortunately, the high cost of many of these instruments and their demand for skilled operators impede wider use in law enforcement. To bring these advances more directly into police operations, improvement in crime laboratories must proceed in two directions:

- Establishment of regional laboratories to serve the combined needs of police departments in metropolitan areas.
- Expansion of research activities in major existing and new laboratories.

The need for the regional laboratories follows naturally from the increasingly expensive facilities and the increasing demand for individuals of superior technical competence. The research is needed to speed the application of new instrumentation possibilities. A national laboratory specifically devoted to research on criminalistics might handle the following complex of functions:

- Maintain close contact with the general science and engineering community so as to become aware of new devices and techniques to expedite their introduction into the operations of crime laboratories.
- Understand the instrumentation needs of crime laboratories and stimulate the industry to develop new instruments to meet their needs.
- Conduct its own research, experimentation, and development of techniques and apparatus.
- Develop a data base for the identification of common crime-related materials by various techniques.
- Disseminate the results of its work.
- Handle cases for local agencies which require specialized equipment and high technical competence to carry out the required analyses.

Because of the wide range of technology involved in criminalistics, and the many opportunities for advanced applications, a broad study directed at identifying the most fruitful of these opportunities should be undertaken.

ALLOCATING PATROL FORCES BY EFFECTIVENESS IN DETERRING CRIME

Basic to the police apprehension system is the overriding problem of the allocation of manpower and equipment in such a manner as to achieve most effectively the department's main objectives of prevention, detection, and apprehension. The importance and magnitude of the problem is evident not only in crime statistics, but in the fact that, nationwide, the patrol function costs approximately $800 million. Manpower allocation procedures which might increase patrol effectiveness by, say, 5 percent, could reflect a possible savings of about $40 million.

All police departments have the problem of allocating patrol forces—how many men to assign to each shift and to each precinct. Related problems amenable to analysis include selecting the size of patrol beats as a function of amount of crime and other demands on the police; optimizing search patrol patterns; and shifting units hour-by-hour into the sections of the city where and when the crime is most likely to occur. These and other patrol-related problems can be analyzed in depth using statistical analysis, mathematical programing, and other operations research techniques. There must be a close tie between analysis and controlled field experimentation to test the results of the analyses.

In allocating patrol forces most departments assign men equally to all shifts, which simplifies scheduling but reflects less than the most efficient use of manpower. The Los Angeles Police Department has a more sophisticated procedure for assigning men to patrol divisions.[16] They use a formula which weights the previous year's crimes, radio calls, population, etc., for each division, and they then assign the patrol force proportionately to the division's weighted score.

For example, if there were 1,000 crimes in Precinct A and 600 crimes in Precinct B, this procedure might suggest transferring officers from Precinct B to Precinct A. But the conditions in Precinct B might be more conducive to deterring crime. If an additional officer in Precinct B could suppress 50 crimes whereas one in Precinct A could suppress only 10 crimes, then it would be desirable to transfer an officer from A to B.

Estimating this relative effectiveness of a police officer is, of course, extremely difficult, since the number of assigned officers is only one of many factors influencing the crime rate. It is, however, important to develop such an estimate to make efficient use of the police force. Statistical techniques, such as regression analysis, can be used

[16] "Patrol Administration" by G. D. Gourley and A. D. Bristow: C. C. Thomas; Springfield, Ill., 1966.

to develop such estimates. Even though the final determination of the effect of an officer on crime must come from controlled experiments in the field, the experiments should be preceded by preliminary analysis so that the experiments can be more productive of both information and crime reduction.

An inherent difficulty in most statistical analysis is its inability to distinguish between cause and effect. For example, in many police precincts, additional officers are assigned as crime increases. Because the additional crime causes additional manpower allocations, the two may appear positively correlated. But this certainly does not permit the blind conclusion that the additional police cause the additional crime. Thus, any results must be used with caution, checking the predictions against actual observations before acting on the results.

The Task Force undertook a preliminary analysis based on limited data contained in the "Statistical Digests" of the Los Angeles Police Department from 1955 to 1965. The statistical technique of regression analysis was used to relate the number of reported serious crimes in each of the department's divisions to the number of patrol officers assigned to the division.[17] In this analysis, an attempt was made to factor out effects due to changes in the population and simple time trends resulting from changing characteristics of the population, thus separating them from the effect of the number of patrol officers assigned. This model could be improved by adding such variables as median education level of the inhabitants and median income, and by replacing total population with population by age groups, when data become available.

Even with this limited effort and the limited data available, in 4 of 11 divisions most of the changes in the numbers of crimes could be accounted for by the model. In the four divisions, the manpower allocation for 1963 was examined and a study made to determine if a different allocation of police assigned to these four divisions might have resulted in an overall decrease in reported Part I [18] crimes. In 1963, there were 824 police officers assigned to the 4 patrol divisions. The approach was to determine a reallocation among the divisions which might reduce the predicted number of Part I crimes. To avoid major perturbations, no reductions of more than 10 percent in the number of officers per division were considered. The analysis suggested that a shift of officers might have led to a net decrease in reported Part I crimes for the four divisions, primarily due to what appeared to be a particularly high officer effectiveness in one of the four divisions.

The validity of such predictions can be determined only by controlled experimentation in which suggested changes and means of measuring their effects are established. Other models should be tried, and better and more complete data on items such as socio-economic factors are required in order to extend and refine the approach. Data collection and experimentation programs should be set up to develop improved procedures for estimating the effects of allocation decisions on crimes and for improving police allocation. This was merely a first limited step in a continuing cycle of analysis, data collection, field test, and analysis. Further theoretical development and trials in actual operations are needed. Several such approaches should be tried to develop methodologies that can be applied by other police departments.

[17] The model used was:

$$C = a + bP + cP^2 + dK + eK^2 + fT$$

where C = number of crimes in the division during the year, P = population of the division during the year, K = number of police assigned to the division during the year, T = number of years since some fixed year, and a through f are constants for the division. The regression analysis was used to estimate numerical values for the constants.

Another possible model might be:

$$C = [gP + hP^2]\,[1 - kK]$$

where g, h, and k are now the constants for the division. Here gP represents an effect due to population, hP^2 an effect due to population interactions, and k represents the "deterrence effectiveness" of policemen assigned to the division. This and many other models should be explored.

[18] The Part I crimes are the Index crimes plus negligent manslaughter and larceny under $50.

Police Operations—Communications, Command and Control

Many aspects of a police department's patrol operation may be likened to a living organism, with sensory organs, nerve networks, a central brain, and motor extremities. Its sensory organs include the means of detecting crime: patrolling officers, alarms, surveillance devices, witnesses, and victims. The primary input network is the public telephone system, and the output network is the mobile police radio network. The counterpart of the brain is the police communications center, which receives the public's calls and dispatches the patrol force in response. The major extremities are the patrol officers who take field action.

With the accelerating trends in telephone ownership,[19] motorization of the police force, and use of two-way radios for police communications, this network has assumed increasing importance. The needs for improvement have expanded faster than its technological development. Fortunately, the potential for improvement is probably greater here than in any other aspect of police operations. The developments to meet the military needs for portable communications equipment and for command and control of military forces provide an extensive reservoir of untapped capability.

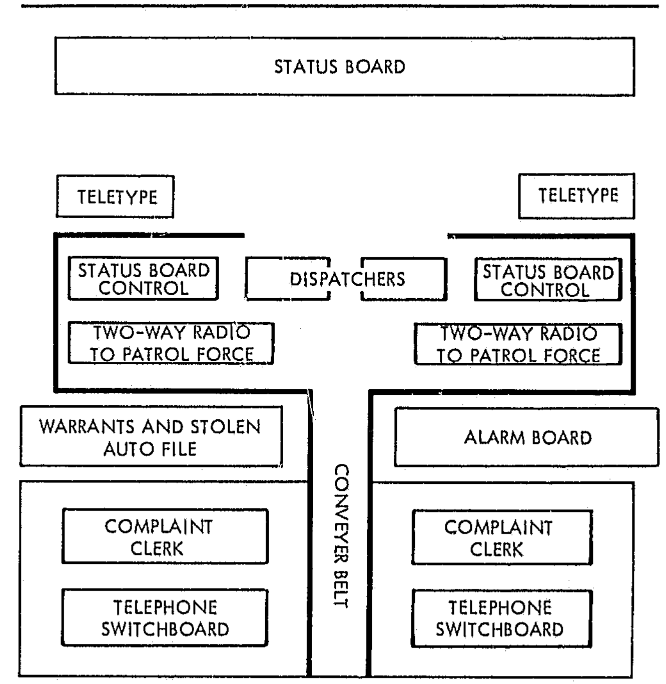
COMMAND AND CONTROL

"Command and control" is military terminology for the planning, direction, and control of operations. It involves the organization of personnel and facilities to perform the functions of planning, situation intelligence, force status monitoring, decision making, and execution. These concepts can also be applied to analogous police operations, leading to the possibility that command and control technology might also be applied. Before discussing these possibilities, present police command and control operations will be described.

PRESENT POLICE COMMAND AND CONTROL OPERATIONS

In most police departments, command and control is performed in the communications center, the focal point of almost all the public's calls to the police. Figure 6 depicts a typical communications center in a large city. Situated in an area of approximately 1,000 square feet are several telephone answering stations; a number of radio dispatchers; a board designed to show the patrol beat assignments and the availability of each patrol car; and associated devices such as clocks and time stamps. Files of street locations, stolen automobiles, and wanted persons are usually present or readily available via telephone, teletype, or pneumatic tube stations.

FIGURE 6. TYPICAL COMMAND-AND-CONTROL CENTER



A call for help first appears as a blinking light on a complaint clerk's telephone switchboard. If all the clerks are busy, the caller must wait until a clerk completes an earlier call. The waiting time depends on the rate of calls, which varies markedly with time of day, and on the number of complaint clerks. There is usually a sufficient number of trunk lines so that busy signals are rare.

[19] There are over 93 million telephones in the United States. ("Statistical Abstract of the United States, 1966;" Department of Commerce; Government Printing Office, Washington, D.C. 1966.)

Obviously, the urgency of a call cannot be evaluated until it is answered. It may concern a crime in progress, a report on an old crime, or a family dispute. Only after he answers a call, in order of arrival, can the complaint clerk determine the type of call, its urgency, and the location of the incident. If he then decides that a car should be dispatched, he writes the information on a time-stamped "complaint card" and sends it to a dispatcher by a conveyor belt, pneumatic tube, or by hand. For extreme emergency calls, he might alert the dispatcher to switch into the telephone conversation; he at least indicates the emergency nature of the call on the complaint card. The dispatcher, when choosing the next card, takes the one with the highest priority. Usually, his only information about the call is the information on the card; he rarely participates in the telephone conversation.

The dispatcher must translate the address of the incident into a patrol district in order to find the car to assign. He may have to refer to a map or a city location file, but he is usually sufficiently familiar with the city to do it by memory. He then checks a status board to see if his selected car, the one he believes to be the closest, is available. At present, the actual location of a patrol car within its assigned beat (generally a radius of 1 to 4 miles) is unknown. Therefore, on an emergency call such as a crime in progress, the call may be broadcast to all units; those within a suitable distance of the scene go to the announced address. This usually brings the closest car, but often results in diverting many unnecessarily. There are many instances, however, when the closest car does not respond at all, since a patrolman in an adjacent beat may not be aware that he is closest to the scene. On a lower priority call one specific car will be dispatched. Once the dispatch order is acknowledged, the dispatcher time-stamps the card, places it in an active tray, and updates the status board.

There obviously exist many variations to the dispatching function described above. In some centers, the same person serves as the complaint clerk and the dispatcher. This arrangement normally requires the individual to be familiar with the addresses over the entire city. In larger cities, where this may be a problem, he may be made responsible for only a part of a city. Then, only those calls originating in his area should reach him; this can be accomplished automatically by making the assigned areas congruent with areas sharing common telephone switching centers. Some cities have current status boards and lights; other cities rely on out-of-date maps or no maps at all. Some cities have backup telephone positions to reduce the telephone waiting time, others have none.

The existing facilities for command and control are especially taxed during general emergency situations such as riots or natural disasters. The communications load increases enormously due to the deployment of many more officers in the field and the general alarm of the public, resulting in telephone switchboards and radio channels becoming completely saturated. The problems are especially complicated by the requirement to maintain reasonable patrol service in areas not directly affected by the emergency.

Most police departments maintain separate fixed and mobile command and communications facilities for use in such emergencies. Nevertheless, the command requirements of information gathering and coordination of large numbers of units (including other agencies such as fire departments, other police departments, and National Guard units) pose great problems to present police command and control systems.

The discussion of present operations suggests a number of critical command and control problems that seriously limit police departments' operational effectiveness:

- ☐ Although a great deal of information about car status and details of a call flows through the communications center, little of it can be readily recalled by whomever may need it. The center gets very little feedback on the results of its actions.
- ☐ At best, the location of patrol cars is only crudely given by their beat assignment.
- ☐ The communications center delay is a significant part of the total response time. Studies in Los Angeles indicate that on the average it takes 1.5 minutes for a priority call and 5.9 minutes for a nonpriority call to be processed through the communications center. The patrol cars take an average of 3.8 and 6.8 minutes to reach the scene of the crime in cases of priority and nonpriority calls, respectively. Hence, the communications center accounts for 30 to 50 percent of the total delay.
- ☐ Most large-city police departments are faced with a severe radio spectrum congestion problem resulting in radio communication queues of patrol officers trying to reach their dispatchers. This situation will grow worse in the future as more cars and radios are added.
- ☐ Staffing is a perennial problem for the police and, as the size and complexity of an operation grows, merely adding more people is not the answer. The problems of information transfer and coordination increase severely as more people are added.
- ☐ A city seeking to improve its operations has no guidelines on how best to design and organize a communications center. The great variability in approach from city to city, coupled with the lack of experimental evaluation of different methods, prevent any consensus on technical or operational approaches.
- ☐ Contingency planning for command and control during emergency situations such as riots or disasters has been neglected by many police departments.

POTENTIAL CONTRIBUTIONS OF SCIENCE AND TECHNOLOGY

There are three ways in which science and technology can help address these problems. The first is conceptual—analyzing the process and drawing on insights

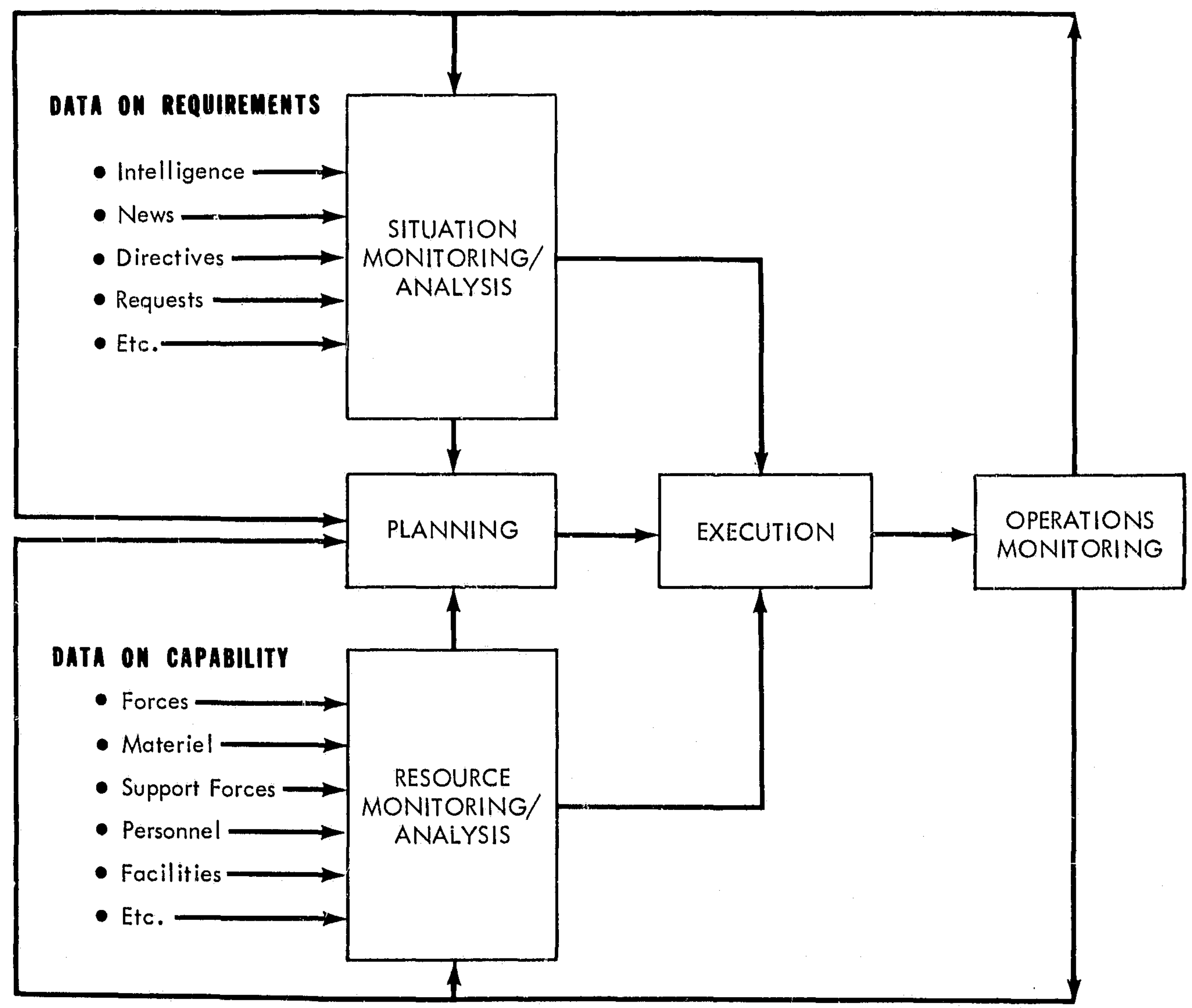
gained in previous related analyses such as those conducted for military command and control systems. The second is in evaluation and modification of existing designs and procedures. The third draws on modern computer technology.

Command and Control Concepts

Effective use of the radio-dispatched mobile patrol force requires knowing at all times where the units are and what they are doing, and matching them appropriately to the public's needs. Information is the essential element in making such assignment decisions: information about criminal activity, the status of police resources, and the environment and general circumstances in which operations must be conducted. The information must be gathered, organized, and displayed in a timely fashion so that it can be utilized for decisionmaking.

As noted earlier, these functions fit the generally accepted concept of command and control. Since the early 1950's the Department of Defense and the individual military services have been intensively developing command-and-control systems to support military commanders. Figure 7 illustrates the functions which are basic to the discharge of command responsibilities. The commander must know the environment and circumstances in which he must operate; this capability is provided by the situation monitoring and analysis function.

FIGURE 7. BASIC COMMAND-AND-CONTROL FUNCTIONS



He must have a steady flow of data on the factors concerning his capabilities; this is provided by the resource monitoring function. These data enable him to evaluate his plans and orders, and if necessary, to change them in response to the changing requirements. This is the command execution function. As events occur and plans and orders are executed, the commander monitors the operations of his field forces and uses this information to revise and update his estimate of the current situation and his available resources. This is the operations monitoring function.

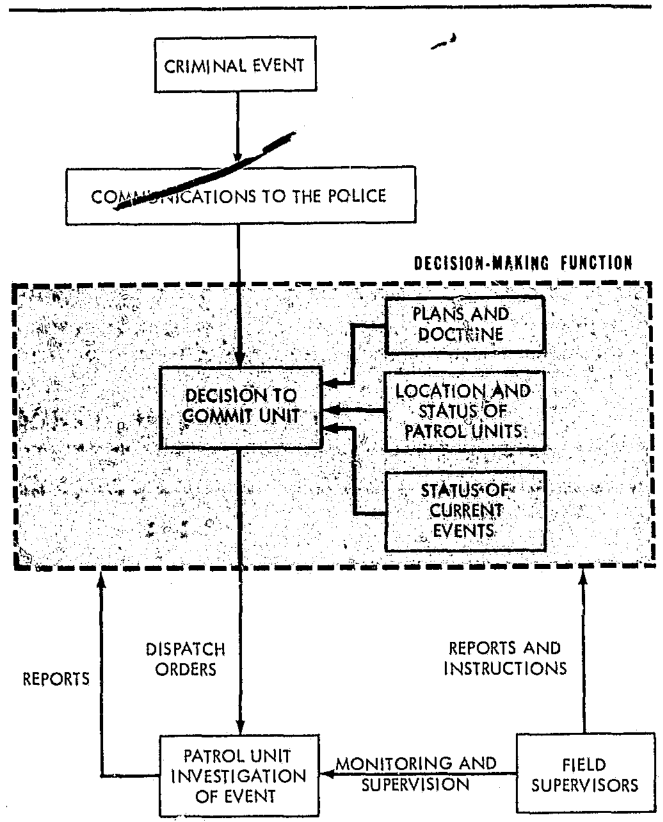
The command-and-control concepts have not been studied or adapted formally in the police context. It is not suggested that police departments adopt the concepts of military command-and-control systems in their entirety. Rather, they can use the general approach, drawing on the many years of research and development supported by the Department of Defense. They can adapt the concepts to their needs, and select those elements that are pertinent. For example, one essential element that should be incorporated into police command-and-control systems is the operations monitoring function. This facility provides "feedback" to the commander to assist him in evaluating the effects of his decisions and to provide him with further information upon which to base his next decisions.

In both military and police work, rapid and complete information gathering, decisionmaking, and dissemination, are of critical importance. As shown in the previous chapter, police response time can often be reduced most efficiently by speeding up the command-and-control function. Selecting the best vehicle to assign in response to a call requires knowledge at the dispatching point of the location and the status of all the mobile units. This implies continual monitoring of the mobile force, and organization and display of the position and status information in a form convenient for decision.

In both police and military operations, decision aids and reliable communications can contribute substantially to improved performance. But the police operation in dispatching and controlling field forces, diagramed in figure 8, does exhibit important differences from military command and control. In the military operations, particularly during peacetime, considerably more emphasis is placed on planning and allocating resources for potential contingencies. In police work, planning and allocation of resources are also important, and will become more so with the application of scientific planning techniques. The heavier emphasis, however, is on the execution phase of command and control.

In a riot or other emergency situation, an emergency communications center must be established to transform a police department from a loose collection of independent units to a cohesive coordinated force. This emergency center, often separate from the regular communications center, must be closely tied to it. Means must be provided to collect and display, rapidly and continuously, all the varieties of tactical intelligence relating to the location of events and the disposition of forces. The center and selected field units might be

FIGURE 8. THE POLICE COMMAND-AND-CONTROL PROCESS



equipped with a radio scrambler for greater security and with frequency-switching or other means of countering attempts to jam their communications. The emergency communications center staff must be headed by a commander who can assimilate this information and who has the authority to command the available forces. Contingency plans for situations that might arise and for coordination with adjacent jurisdictions must be developed and stored in a readily accessible form.

Improvement of Existing Systems

Before considering introduction of major new technology some immediate steps can be taken to improve command-and-control operations. Improving such simple aspects of command and control as floor layouts, design of headsets and microphones, use of foot switches for radio transmitters, and clear and intelligible status displays can improve a center's operation under heavy load.

Communications center procedures and design, which can affect performance significantly under critical loads, appear to have evolved more from local tradition and physical restrictions than from careful planning. The performance of each of several different possible configurations can be experimentally measured, both in operating centers and under laboratory control in a

simulation laboratory. A command-and-control center operates almost entirely with telephone inputs and radio outputs. It has very little direct physical contact with the outside world. Therefore, for experimental purposes it is easy to substitute simulated events for real ones, and to conduct tests on reasonable analogies of real situations. In this manner, standard and emergency plans and procedures can be tested, decision rules can be evaluated, and training and experience can be provided police officers under simulated extreme conditions.

Computer-Assisted Command and Control

The most dramatic way technology can assist command-and-control operations is through the introduction of modern information processing and communication technology. To benefit fully from the technology, however, its introduction should not be limited to simple mechanization of existing procedures which were developed in the face of technological constraints that may no longer be relevant. Rather, the entire police command-and-control function, including many aspects of patrol operations, should be subjected to a basic reexamination, taking full account of the new capabilities offered by computers and communications links. This review should consider questions of when, where, and how to use the police patrol force. It should evaluate how police should respond to various types of routine and emergency situations. It should examine by study and by experiment the extent to which preventive patrol deters crime, how forces should be allocated by time and by geography, optimum patrol tactics, appropriate conditions for conspicuousness and for covertness, how to respond to riots, and many other germane questions. The patrol operations will then be able to benefit markedly from computer assistance—much more than by merely automating existing procedures.

It is possible to describe the general outlines of a computer-assisted command-and-control system for certain large cities.[21] In such a system, depicted in figure 9, telephone calls to the police are still answered by a complaint clerk, termed in the figure a "controller." He enters the type of incident, the address, and a priority code into a keyboard connected to a computer. The controller can specify what the situation requires: whether a one- or two-man car should be sent, whether two vehicles should respond, etc. After he decides that a car should be sent, the rest is then automatic.

The computer maintains records of street-address locations and the location and availability of each patrol car, and finds the best car to respond to the call. It prepares a dispatching order which is automatically sent to the selected car as a computer-generated voice message or by some digital data link such as teletype. If the patrol officer does not acknowledge the message by voice or by some simple digital link within, say, 10 seconds, another car can be sent on the call.

The location file can also report the firehouse or hospital nearest the event, and physical or other characteristics of the assigned address (e.g., three-story building, location was robbed last month). This information can be relayed to the field unit as it proceeds to the location. If the files of stolen automobiles and wanted persons are stored in the computer, the patrol officer might interrogate the computer directly via a direct data link without going through the dispatcher. This would decrease the processing time for such inquiries and the amount of traffic on the voice-radio frequencies.

Burglar and other alarms could be linked directly to the computer. If an alarm went off, the computer, knowing the alarm's location, could immediately dispatch the appropriate car without the controller's intervention.

The dispatch orders, the status of the patrol cars, events in progress, and other basic control information can be displayed by the computer to command officers, who can always countermand the computer-originated orders. They can concentrate on the unusual while the computer automatically handles the routine.

The total delay time in the control center would be reduced to the time it takes for the controller to enter the information from the caller into the computer and to get the message onto the air. The current processing times of several minutes could be cut to 30–60 seconds. The computation time would be an insignificant part. The radio transmission time can be reduced by the use of patrol vehicle teleprinter discussed later in this chapter.

Since field response time depends strongly on the assigned car's distance from the call, automatic car-location devices could be tied directly to the command-and-control computer, so that it could find and dispatch the closest car. Car locater devices would permit assignment of the two or three cars closest to the scene, and if advisable, other cars could be strategically deployed along escape routes.

Fortunately, as is shown in appendix E, most of the advantages of having a car locator can be achieved with comparatively inaccurate devices, errors of about one-quarter mile being acceptable.

There are four techniques that show promise of providing the necessary accuracy of an acceptable level of cost:

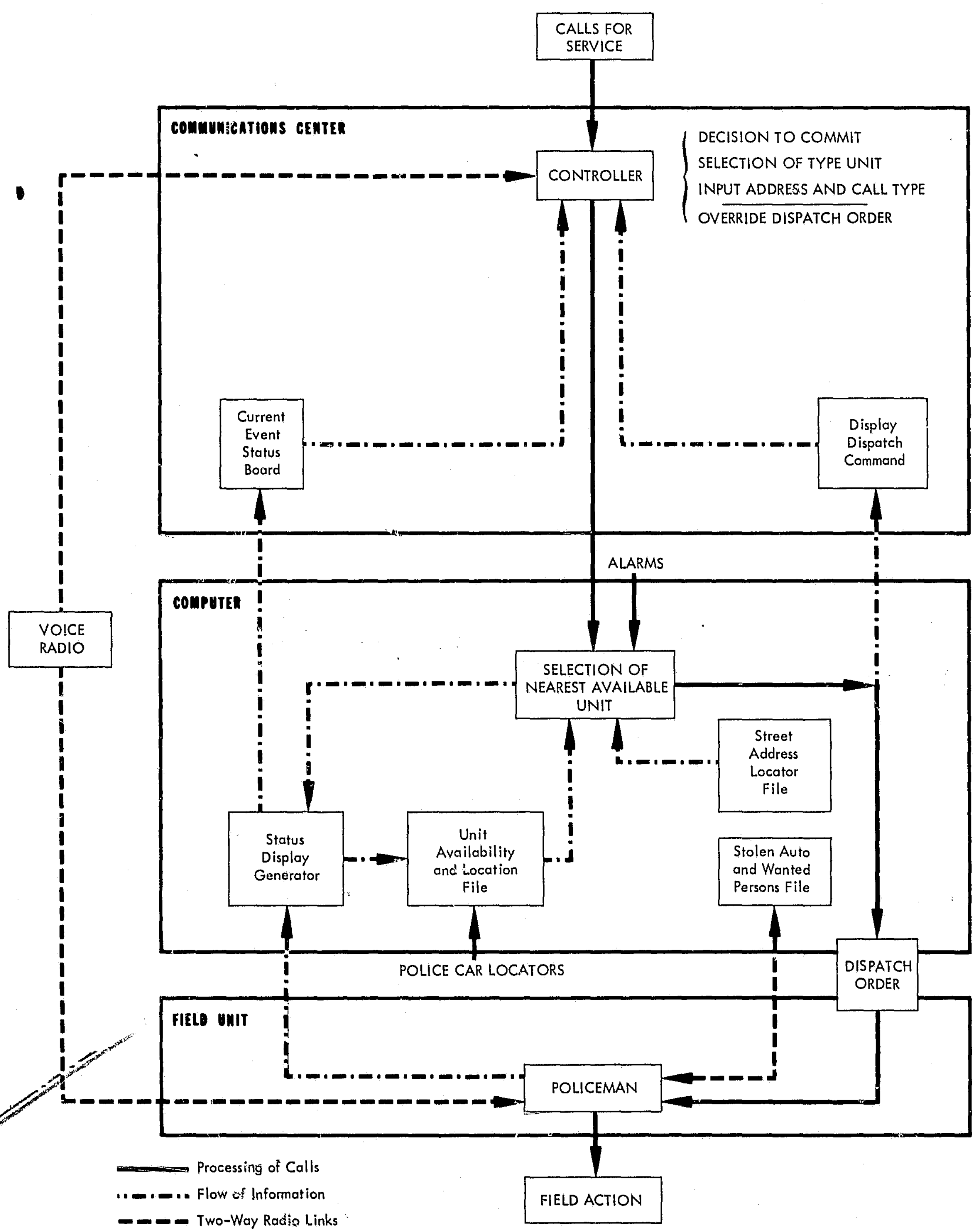
- A system of police car emitters and callbox sensors.
- A modified radar transponder system.
- A medium frequency radio-direction-finder system.
- A carborne position computation and reporting system.

These are discussed in appendix E.

In the patrol car emitter-callbox sensor system each car would carry some kind of a visual, acoustic, or electromagnetic identifying emitter that could be detected by receivers located in police and fire callboxes. Information gathered by the sensors could then be sent back to the communications center by land lines. The inverse of this technique could also be employed, with coded emitters installed along the street and sensors installed in patrol cars. A radio link would then be needed in the car to relay the car's identification and location to the communications center.

[21] The New York City Police Department, with its SPRINT system, is already taking some significant steps in this direction.

FIGURE 9. POSSIBLE COMPUTER-ASSISTED POLICE COMMAND-AND-CONTROL SYSTEM



In Washington, D.C., for example, there are approximately 920 police callboxes, located as shown in figure 10. There are about 14 callboxes per square mile or approximately one every quarter mile. This would provide sufficient precision for patrol car location. If finer precision was desired, consideration could be given to locating sensors in the 2,000 fire callboxes.

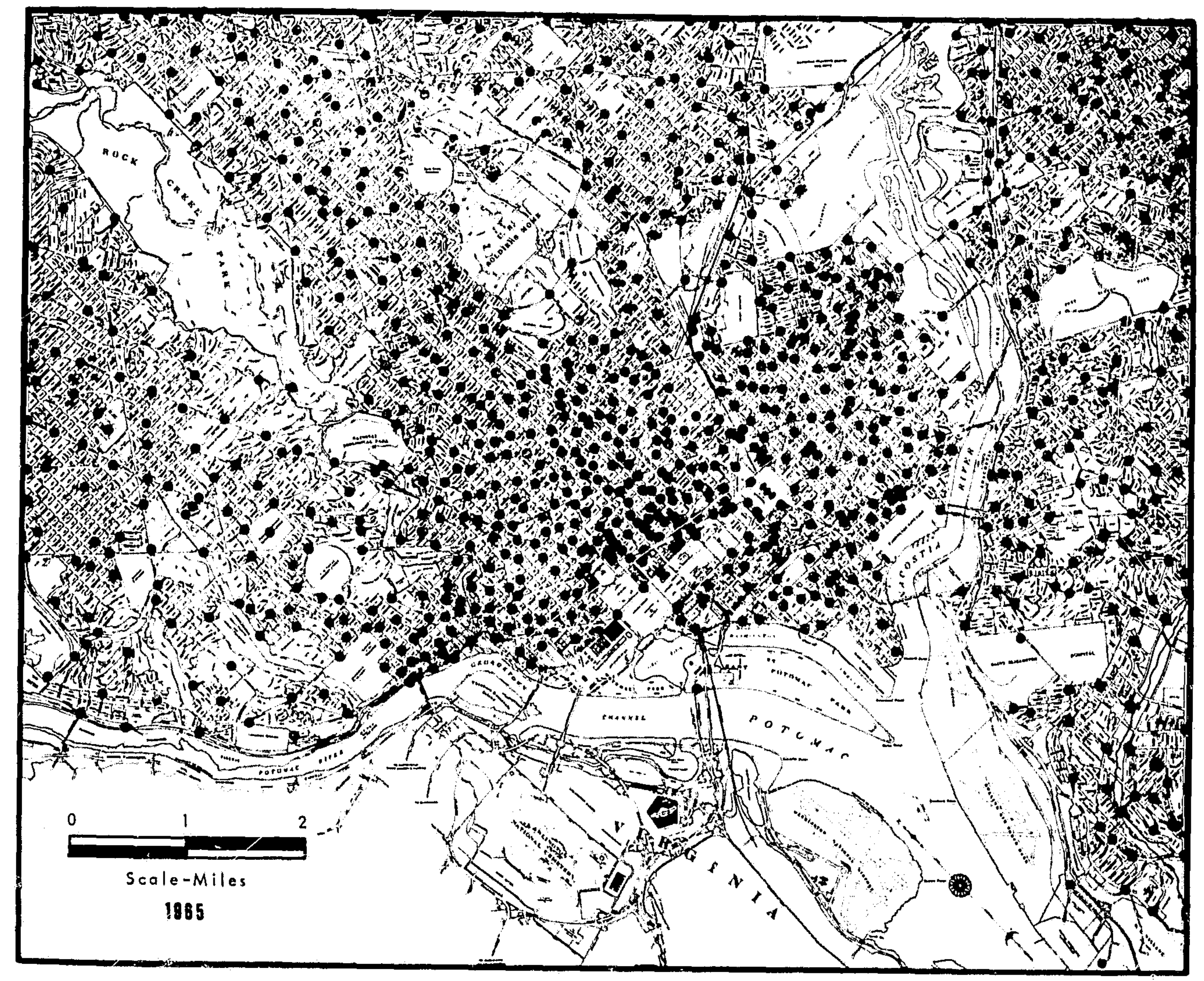
Use of a radar system requires special transponder techniques to overcome reflections from the numerous buildings, towers, and other structures in a metropolitan area. One possible approach would be to use a central interrogator, transmitting pulses through a directional antenna. Each police car's transponder would reply to an assigned interrogation pulse a specified interval after a synchronization pulse.

A medium-frequency radio direction-finding system can determine the direction of a radiating transmitter even when the transmitter is located in the midst of tall structures. Conventional direction finders employing triangulation techniques could therefore be used to locate police cars equipped with a simple low-power medium-frequency transmitter. The police radio frequencies in the 2–3 MHz range should be suitable for this application.

In a carborne position computation and reporting system, the patrol car would continually compute and record its own location with an integrating compass, odometer, and resolver computers. It could transmit that information upon receipt of a proper interrogation signal.

All four of these basic car locator techniques appear to be technically feasible. On the basis of this limited in-

FIGURE 10. POLICE CALL BOX LOCATIONS IN THE DISTRICT OF COLUMBIA



vestigation, the patrol car emitter-callbox sensor system appears to offer the most promise where a network of callboxes or some equivalent exists. The modified radar transponder system if it proves to be feasible may be preferred elsewhere. Preliminary design studies of both of these systems should be undertaken to obtain an estimate of feasibility, costs, and performance.

The location of the incoming telephone call might also be determined automatically in order to reduce the time spent by the controller to insert information by the keyboard. The telephone company could record the number of each incoming telephone call, determine that telephone's address from a computer file of telephone addresses, and display that address to the controller, as he answers the call.[22] By punching a button, he could enter the correct address directly into the computer. This would save time and reduce the chances for error. Since the calling telephone may not be at the location of the event, however, manual addressing capabilities would have to be retained. Furthermore, automatic recording of addresses might discourage callers who wish to remain anonymous from reporting incidents to the police. It is not clear whether the cost of such capability warrants its use, but it is a capability to be considered.

A computer-assisted command-and-control system offers many new possibilities for the deployment and control of a patrol force. As the crime pattern in a city changes hour-by-hour, its patrol force could be redeployed to respond to it. As parts of the city are stripped of patrolmen by called-for services, other units could be assigned as backup. Under a riot or other emergency situation, contingency plans could be programed so that appropriate units would be deployed to the emergency, and adequate backup maintained.

With all information on calls stored in the computer, complete analysis of the operations of the patrol force could be conducted regularly to aid in assigning forces in response to changing crime patterns.

Under these computer-assisted command-and-control concepts significant organizational changes would be needed. True command and control of the field units would be delegated to the center—the precinct watch commander would know what is going on in each beat and the status of each unit only if he was at the center in the role of a dispatch commander, or if he were given a remote display at the precinct station.

It is estimated that the total operating cost of such a system for a 100-car city would range from $500 to $2,000 per car for new equipment, $200,000 to $400,000 per year for computer rental, a similar amount for computer personnel, plus $500,000 to $2 million for control-center equipment and design.

Since the system must operate reliably 24 hours a day, a backup computer must be provided and is included in these cost estimates. In measuring the impact of the cost of these items on a police budget, it is relevant to note that a two-man patrol beat costs about $100,000 per year. The command-and-control computer system could also be used to perform the other statistical and reporting functions of the department during slack hours, and that function would bear some of the cost. A cost savings would be realized by the replacement of dispatcher personnel, since a city with 10 radio dispatchers could probably reduce the number to three or four dispatch commanders, but this would probably be canceled by the addition of computer personnel. The number of telephone controllers would stay about the same.

The proper design of such a system and the procedures for using it can only be developed in an evolutionary way. Furthermore, additional information is needed to delineate what size departments can benefit sufficiently to warrant the cost. It does appear, however, to offer sufficient potential for a major breakthrough in patrol operations to warrant pursuing it in depth. A great deal of analysis and experimentation should precede and accompany the implementation of such a computer-assisted command-and-control system. Many possible equipment combinations will have to be weighed and basic organizational and procedural questions examined in developing the final system.

PROPOSED PROGRAM

The next step in improving police command and control would appear to involve significant research and development programs requiring Federal funds. An experimental program to develop a computer-assisted command-and-control system should be established with Federal support. The following sequence of developments should be undertaken to proceed with such a program:

- ☐ Two or three large cities should be funded by the Federal Government for a detailed study of their patrol operations to determine how they would use a computer-aided command-and-control system.
- ☐ As part of the effort, an extensive reexamination of the communications system should be undertaken to assure the proper channel availability and to assess the utility of car locators, mobile teletype, and automatic address location from the telephone.
- ☐ Based on the results of the studies, one of the cities should be selected for installation of a prototype system.
- ☐ As the new system is developed, it should first be used in simulated operation in parallel with the manual system, then with a manual backup, and finally, be incorporated into the control operation.

The development process will have continual modification and testing and should be guided by an organization experienced in the development of large, computer-based systems.

Federal support should also be given to experimentation on communications center design and procedures, both in operating communications centers and in a simulation laboratory created for that purpose.

[22] A study prepared for the task force by American Telephone & Telegraph Co. suggests the feasibility of this approach.

COMMUNICATIONS TO THE POLICE

The primary input to the command and control system, and the most frequent initiator of the apprehension process, is a call from a citizen, usually a victim of a crime or a witness to one. In the case of street crimes, however, it is often difficult for the victim or a witness to call the police promptly. A number of things can be done to improve existing street communications equipment to make it easier to reach the police.

The victim of a robber careful enough to steal his last dime cannot now use the public telephone. Public telephones can be adapted so that the operator can be reached without using money, as was demonstrated in a recent test in Hartford, Conn., and as is now possible with equipment used by some small telephone systems. The Bell Telephone System is now planning to extend this capability widely.

Most major cities have a network of police callboxes that are usually inconspicuous and locked, in many cases about as numerous as street telephones. Washington, D.C., has, as noted, 920 such boxes, or about 1 every quarter mile. These are not now available to the public. During World War II, however, they were painted red, white, and blue, and made available to the public in case of air raids and other emergencies. Adapting callboxes to permanent public use would, at little cost, double the number of available locations from which citizens could notify the police of observed street crimes or auto accidents.

The false-alarm rate for such callboxes would probably be less than from a mechanical alarm, since a potential prankster would have to reveal his voice. While experience with a police callbox may not turn out to be fully comparable, one metropolitan fire department estimates the false alarm rate for calls received over the telephone to be less than 3 percent, far less than the 50 percent false-alarm rate for an automatic or a mechanically actuated alarm.

Simply adapting a callbox system for public use is not sufficient to obtain maximum benefits. Each public callbox must be well marked and lighted; they must be easy to operate; and the availability of the system must be widely publicized. Apparently these necessary steps have not been taken by the majority of U.S. cities today.

A survey revealed that in five cities an average of only about two alarms were sent from each callbox in a year. Informal surveys have indicated that less than 10 percent of the population is aware of the presence and methods of use of the public alarm system. Merely providing such an additional communication link to the police without publicizing the benefits which an aware public can derive is leaving the task half completed.

Police callboxes should be designated "public emergency callboxes," should be better marked and lighted, and should be left unlocked. Since the foot-patrol supervision function, for which most callboxes were originally intended, is rapidly becoming unnecessary through more widespread use of radios, the public alarm function is probably the major reason for maintaining such systems at all.

When trying to call the police from an ordinary telephone, a person is faced with a bewildering array of police jurisdictions and associated telephone numbers. In the Los Angeles area alone, there are 50 different telephone numbers that reach police departments within Los Angeles County. It should be possible to use a single telephone number to reach the appropriate police department (or some other emergency center) directly. Great Britain has such a universal emergency number, "999."

Wherever practical a single number should be established, at least within a metropolitan area and preferably over the entire United States, comparable to the telephone company's long-distance information number. This is difficult but feasible with existing telephone switching centers; it appears more practical with the new electronic switching systems being installed by the telephone companies, and should be incorporated. In the interim, the telephone companies should print on each telephone number disc the number of the police department serving that telephone's location.

Once the caller reaches the police, he may be delayed because all the complaint clerks are busy.

The delay time can be reduced by adding complaint clerks, and an appropriate number can be calculated, as was illustrated in the example in chapter 2. On the basis of analyses[23] the following general conclusions can be drawn:

> Large police departments should have at least two telephone numbers—one for emergency calls and the other for administrative calls—with the ability to transfer calls from one line to the other.
>
> Telephone traffic studies should be performed so that the rate of calls can be estimated as a function of the day of the week and the time of day. An appropriate number of telephone clerks can then be assigned at all times.
>
> Similar studies could be conducted to determine the optimum number of dispatchers as a function of the call rate, the number of cars on patrol, and the radio conversation times.

POLICE RADIO COMMUNICATIONS SYSTEMS

Information flows from the communications center to the mobile patrol force almost exclusively by voice radio. As discussed in appendix D, police departments throughout the country are now faced with many complex problems and serious limitations on their plans and activities due to congestion of the radio spectrum. Some characteristics of the difficulties are:

> Congestion is most severe in major population centers.
>
> In most areas, police radio is organized into small independent networks, resulting in inefficient use of available frequencies.

[23] The analyses are in a report, "Analyses of the Police Apprehension Process," now in preparation. The report will be available from the Clearinghouse for Federal Scientific and Technical Information of the National Bureau of Standards.

With a few notable exceptions, radio communication is based on the same operational concepts as in the 1930's.

Congestion will intensify as more mobile radios are used and as additional communication devices such as portable radios and radioteletypes are introduced.

Little effort has gone into planning or accumulating the data necessary to estimate either present or future radio spectrum requirements as a function of time, location, and frequency; nor have these requirements been presented in clear-cut terms for consideration by the FCC.

Although data detailing the national radio spectrum shortage are particularly difficult to obtain, individual examples from many areas are sufficiently dramatic to make a compelling case for the reality of the shortage in many metropolitan areas. In the Chicago metropolitan area, for example, 38 separate suburban cities with 350 patrol cars must share 1 frequency. This congestion results in excessive delays and underuse of the police force while patrol officers wait to gain the air. No police officer who needs help should have to wait for a clear frequency.

An emergency message from a police dispatcher always has top priority and, even in extremely congested police radio networks, that message gets through. However, the radio spectrum congestion evidences itself in less obvious ways. For example, some police departments have limited the number of police cars on the streets because of lack of radio capabilities. Others have delayed purchasing such new equipment as small, portable radios for patrolmen on foot for similar reasons. Thus, the spectrum shortage generally manifests itself gradually by limiting the use of modern technology, rather than in immediate dramatic ways.

The breakdown in police radio communications networks becomes dramatically evident in major disorders and in similar situations demanding the coordinated action of a number of police agencies. At such times, both the congestion and the lack of flexibility of the police networks become glaring weaknesses. Thus, in the Watts riots of 1965, both the police agencies directly involved and the police brought in from other parts of Los Angeles attempted to use hopelessly congested channels or could not communicate at all because of frequency incompatibility. Some police commanders were unable to talk with men assigned to their command; it is extremely difficult to try to control a civil disturbance in an area of 40 square miles without effective communications. In Illinois, when State, county, and municipal police have monitored disturbances, their coordination has similarly been hampered by lack of radio contact.

THE DESIGN OF POLICE RADIO NETWORKS

An efficient police mobile radio network should make greater use of trunk groups of channels rather than single channels, and it should have a number of "switchable" channels which can be reassigned from one group of users to another as current demands change.

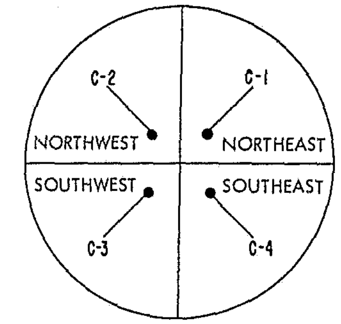
In radio communications, a receiver can be designed so that it is turned on upon receipt of a subaudiofrequency code. Thus, by the use of the subaudiofrequency code, it is possible to communicate with a chosen car or a group of cars equipped to respond to the code. Other cars tuned to the same frequency but responding to a different code can be addressed separately at different times. This coding permits greater flexibility in the use of each frequency. The same channel may be used at different times for detective work, for addressing supervisory vehicles alone, or for citywide purposes by variation of the code. Although some switching capability can be achieved without the use of selective coding, obviously much greater flexibility is available through its use. Hence, police departments should make greater use of selective coding for addressing in their radio networks to enable them to switch their radio channels to meet their changing demands.

Police radio networks should also make greater use of multiple frequency trunking. The trunking concept is illustrated in figure 11. The top of figure 11 depicts the method currently used to provide radio coverage for a police mobile fleet. The city is divided into a number of major geographical sectors, each one patrolled by usually no more than 50 vehicles. The number of sectors is the same as the number of radio channels used, four in this example. The vehicles assigned to a sector are all linked to a dispatcher in police headquarters by the same single radio channel. The channel may be simplex (the cars and the dispatcher all use the same frequency) or duplex (one frequency is used by the dispatcher and another is shared by the cars).

The middle of figure 11 shows the simplest version of multiple frequency trunking. The sectors are paired and two channels are assigned to each pair to use in common. Patrol vehicles still communicate only with their own dispatcher, since addressing is accomplished by selective frequency coding rather than by simple frequency addressing. The individual user in the top situation will sometimes find the channel busy when another car in the same sector is using it. In the middle case, both channels must be busy simultaneously for the user to experience delay in placing his call.

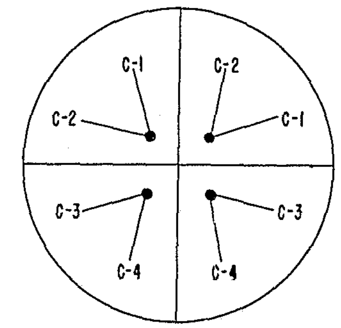
Even though the demand on the two channels is twice that on one, delay is less likely to occur when the channels are shared, since each car can use either of its assigned channels. For instance, if each of two sectors uses its private channel 50 percent of the time, then each one finds it busy half the time. When sectors are paired, a user would find both channels busy only 35 percent of the time. Thus, both have better service with the shared arrangement. In the bottom figure, all four channels are shared by all the sectors in a trunking arrangement, and delay is still less likely, occurring 20 percent of the time in the above example. In this case all four channels must be busy simultaneously for a call to be delayed. These principles are utilized in conventional telephone networks, in the AT&T mobile radio service, and in electric-power networks.

FIGURE 11. ILLUSTRATION OF MULTIPLE CHANNEL TRUNKING



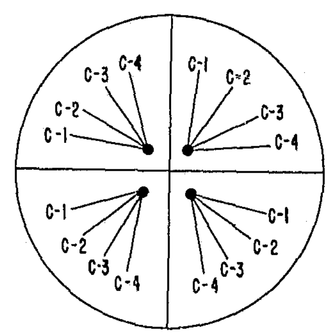
CONVENTIONAL NETWORK

CITY DIVIDED INTO FOUR SEPARATE SECTORS. EACH WITH ITS OWN RADIO CHANNEL AND DISPATCHER.



MINIMUM TRUNKING

SECTORS PAIRED TO SHARE TWO RADIO CHANNELS. SELECTIVE ADDRESS CODING PERMITS EACH SECTOR'S CARS AND THEIR DISPATCHER TO TALK ONLY WITH EACH OTHER.



COMPLETE TRUNKING

ALL SECTORS SHARE ALL CHANNELS. SELECTIVE ADDRESS CODING PERMITS EACH SECTOR'S CARS AND THEIR DISPATCHER TO TALK ONLY WITH EACH OTHER.

Geographical and topographical features limit the manner in which sectors could be combined. In Los Angeles, for example, two major sections of the city are divided by a line of mountains, so that only sectors on the same side of the mountains could share channels.

A number of problems more directly related to police communications further limit the simple application of these concepts. The dispatcher, for example, is often the limiting bottleneck in mobile radio communications. It may well be decided in a particular situation, therefore, that multiple frequency trunking should not be applied to the dispatcher's messages, and that he should have his own exclusive channel to eliminate the possibility of delaying him. This could be done with a duplex system in which the dispatcher's frequency is private and the incoming calls trunked.

The growth of police mobile radio networks has led to an increased control of the police mobile forces by the dispatchers, and a corresponding diminution of the effective authority of the sergeants and lieutenants in the field. Some police departments insist that all cars in an area be able to monitor all calls, partly for improved coordination, partly to permit the field supervisors to exercise their functions. This requirement tends to favor the use of a simplex system where both dispatcher and cars talk on the same frequency. Simplex operation also permits car-to-car conversation, which aids the field supervisor and facilitates field coordination. Radio discipline is required to insure that the channels are not dominated by lengthy conversations between cars in the field during those busy hours when the dispatcher must have ready access to the network.

Simplex operation with selective coded addressing would appear in general to offer the best combination of characteristics for general police radio use. By selective addressing, the sergeant could address directly the units under his control without going through the dispatcher. By the same means, all the cars under the direction of that sergeant could monitor the conversation between the sergeant and any car in his tactical unit. Further, in case of a large-scale disturbance, the car-to-car communications capability should make it possible for the group of cars to be separated from dispatcher control and to operate as an integrated field force under the direction of their own supervisor. These features can be obtained in a duplex system but are generally less expensively realized with simplex. Hybrid systems for operating in different modes at different times are, of course, possible.

Trunking makes possible the more even loading of multiple radio channels. This advantage cannot be realized in the small networks of many independent municipalities. Furthermore, these independent networks hamper the ability of neighboring police departments to carry out coordinated actions in major emergencies. These are strong reasons for discouraging their further development. This does not imply that an independent municipality should not have its own independent police force. The conclusion is only that such police forces must coordinate their communications needs with those of other forces in the same area if police communications problems are to be solved in an orderly way.

Channel switching implies that there exist radio channels available to be switched. Such channels do exist in the public safety bands. Highway maintenance and school bus frequencies generally are used only during the normal working day. Busy hours for the police, when these switchable channels are needed, are evenings and weekends. Thus, greater use of trunking and switching urges that the total radio resources of the city be considered in designing a public-safety radio network. The unused frequencies of other public safety users should be made available by appropriate FCC rules to relieve police radio traffic congestion at their peak periods.

Police mobile radio networks using these concepts will admittedly be more costly than they have been in the past. Very preliminary estimates made on the basis of telephone company experience with its mobile telephone service are that costs can be expected to increase by 50 to 200 percent over those of present systems. Where communications are congested and additional frequencies are not readily available, the benefits derived in terms of increased police operational capability would be sufficient justification for the additional investment.

In using these concepts, police agencies will be forced to direct more attention to their network design requirements. Police radio networks are now largely built around the available equipment rather than designed in response to police needs. Police agencies should translate their needs into a system design and then decide what equipment they need.

THE RADIO SPECTRUM CONGESTION PROBLEM

Design of effective radio networks is aggravated by the severe spectrum congestion in the police radio bands, particularly in large metropolitan areas, a congestion extending across all the radio bands allocated to land mobile operations. Limited field tests undertaken by the FCC in Los Angeles and New York, the preoccupation with the subject in the APCO Bulletin,[24] a study made by the Land Mobile Section of the Electronic Industries Association,[25] and evidence gathered and presented in connection with various dockets that the FCC has opened in recent years,[26 27] all indicate serious congestion and a growing demand for more frequencies on the part of radio communications users. FCC Commissioner Cox, in a recent article addressed to the engineering profession,[28] pointed out the rapid growth in the land mobile services (from 10,999 licensed transmitters in 1948 to over 220,000 in 1965) and the reasons for creation of the Advisory Committee for Land Mobile Radio Services. The need for action in this area has also been pointed out in Congress.[29]

The lack of a clear measure of the spectrum available and of a firm estimate of what is needed hampers a clear exposition of the situation. Consider first the needs. Actual channel loading, measured as the percentage of time a radio channel is in use, would be extremely heavy if the channel were in use over 50 percent of the time. Informal surveys made by members of the Task Force show a wide variation in police radio channel loading within the same area. One major police department had a heavy load on several of its channels, but one of its channels was very lightly loaded. However, because of the inflexible network design, the department could not easily switch channels from one set of users to another. In many other cases, small municipalities adjacent to central cities with badly overloaded facilities were found to have lightly loaded channels used only 5 percent of the time. Thus, radio channel loading averaged over a metropolitan area is not a clear-cut indicator of the spectrum congestion.

The radio channel requirements might be keyed to population. Sample statistics indicate that on the average, over a 24-hour day, a police patrol vehicle handles about one call per hour.[30] A population of about 25,000 generates an average of 1 call per hour for police service.[31] Thus, subject to a more detailed evaluation, an average of 1 patrol car is needed on constant duty for each 25,000 of population if demand peaks are ignored. But a communication system must be designed for peak rather than average traffic. The peak demand is typically about five times the average demand; thus 1 patrol car would be needed for each 5,000 population to meet a 5:1 peak.

Studies by the RAND Corp.[32] indicate that a police conversation lasts 25 to 60 seconds on the average. This is consistent with the FCC rule of thumb that 50 to 60 mobile units make a maximum load for a single radio channel. Assuming 30 cars per radio channel as an acceptable working level, this indicates an assignment of 1 radio channel for every 150,000 population. However, the validity of this guideline requires further verification. The need for special channels for supervisory vehicles, detective channels and other special requirements of the individual department represent an additional demand for channels. Furthermore, since municipal, county, and State police operate communications networks over areas where political boundaries have no relationship to the range of a radio transmitter, it would be unwise to apply rigidly a single guideline for determining the actual police radio needs.

The most feasible sources for additional radio spectrum space are the television bands. There are two major sources for additional radio spectrum within these. The first is in the VHF spectrum used for channels 2 through 13. In cities where a particular VHF channel is not utilized, those channels could be made available for police mobile radio systems. Available VHF–TV spectrum can provide on the order of 300 additional channels in most metropolitan areas. The second source of TV frequencies is the underloaded UHF spectrum. The FCC should make space from these sources available for police mobile radio use. If this allocation were to the land mobile services generally, instead of for exclusive police use, the police should receive a major share.

THE RELATIONSHIP BETWEEN THE LOCAL COMMUNITY AND THE FCC [33]

Matters of frequency assignment presently come to the FCC on a piecemeal basis. Although the FCC has urged users to consider and present the broader implications of their requests, the actual workings of the frequency assignment system have led to keen competition for ever-scarcer frequencies on a highly individual basis. Frequency assignments made on this basis have led to wide variations in traffic loading on the police frequencies in all areas. The resulting inefficient use of the radio spectrum has intensified what, in many areas, would be a serious spectrum congestion problem even with efficient use of frequencies. Another result has been that the FCC does not get the kind of overall picture of spectrum usage which would enable it to establish the coherent national policy so necessary to the interests of all concerned.

[24] Bulletin of the Associated Public Safety Communications Officers (APCO).

[25] Land Mobile Section of the Electronic Industries Association, "Study of the Federal Communications Commission Frequency Cards," 1964.

[26] "In the Matter of an Inquiry into the Present and Future Requirements of the Public Safety Radio Services for the Allocation of Radio Frequencies," FCC Docket 11997.

[27] "In the Matter of an Inquiry into the Optimum Frequency Spacing Between Assignable Frequencies in the Land Mobile Service and the Feasibility of Frequency Sharing by Television and the Land Mobile Services," FCC Docket 15398.

[28] Kenneth A. Cox, "The Land Mobile Radio Services," IEEE Spectrum, vol. 2, No. 10, October 1955, pp. 42–43.

[29] John D. Dingell (16th District, Michigan), "The Need for Additional Radio Frequencies," Congressional Record; Sept. 28, 1966, pp. 23207–23216.

[30] FCC Docket 11997, op. cit., "Preliminary Statement," p. 19.

[31] Data derived from City of Chicago.

[32] Personal communication with A. Hiebert.

[33] The material in this section has been reviewed by appropriate individuals in the Federal Government and in police work. Organizations from whom such assistance has been received include the Federal Communications Commission, the President's Office of Science and Technology, the President's Office of Telecommunications Management, Association of Public Safety Communications Officers, International Association of Chiefs of Police, the Police Departments of Wahington, D.C., Los Angeles, Calif., and Burbank, Calif., and the Public Safety Coordinating Committee. Acknowledgement of this aid is not meant to imply endorsement of the material.

Steps should be taken to encourage pooling of radio frequency resources into efficient communications networks on the part of Public Safety Radio Service users;[34] to reduce the number of applicants who deal directly with the FCC; and to require municipal governments to take a greater responsibility for the efficient use of the radio spectrum resources under their control.

As one means for achieving this coordination, the FCC should limit in terms of population and/or land area the size of municipalities located in congested metropolitan areas with which it will deal directly in regard to frequency assignments in the Public Safety Radio Service. To qualify for frequency assignments, such smaller municipalities should be required to participate in an area network plan or coordinate with the central city. Such a policy would encourage cooperation without dictating how this should be accomplished on a local level. Some cases will undoubtedly exist where it is impossible for a small community to enter into such a network. The FCC rule could certainly allow for such exceptions. It is also possible that there will be cases in which a small community is unable to reach satisfactory agreement with a large one. If this should occur, a plan could be presented, along with the dissenting position of either or both groups, for FCC decision.

There are many examples of small communities with lightly loaded channels in metropolitan areas with heavy radio congestion. The FCC should notify these small municipalities that, unless they show justifiable cause for an exception, they must release within 5 years, any public safety frequencies which have been assigned to them. Since FCC licenses are issued for periods no longer than 5 years, this involves a decision not to renew licenses rather than to revoke existing ones.

This action would bring into coordinated networks those municipalities whose motivation to do so is now only limited—their frequency situation is satisfactory although they may be surrounded by others with severe congestion. There appear to be a sufficient number of such communities and sufficient radio spectrum resources are involved to make this an important consideration.

As soon as practicable, the FCC should establish a policy of assigning Public Safety Radio Service frequencies only to the local government and not assigning them directly to the users such as police or fire departments. Frequency advisory matters should be handled by one committee in each geographical area instead of by separate committees for police, fire, highway maintenance, and forestry conservation. These committees should receive formal recognition by their State governments or on an interstate basis.

Police communicators often do not use frequency resources available to their municipalities primarily because these frequencies are not licensed for police use. The FCC has recognized the need for multiple use of radio frequencies by establishing within the Public Safety Radio Service a band of local government frequencies which can be used for any legitimate local activity. The majority of the frequencies in the public safety bands are, however, specified for type of user and forbidden to users not in the specified category. As a result, although a city may have sufficient total radio spectrum resources to create a highly efficient network including all departments, the police may be desperately short of frequencies. This situation is not likely to change in the absence of outside pressure for an overall network plan.

The primary responsibility for allocating frequency resources among police and fire protection and other municipal functions properly rests with the local government rather than with the FCC. The present policy of assigning frequencies below the municipal government level is, to some extent, inadvertently injecting the FCC into local government affairs, increasing the difficulty of its own task, and placing artificial restraints upon the municipal government. This, of course, was not a problem before radio spectrum became congested. Under the broader characterization of the frequencies involved, the FCC retains its responsibility to see that there are adequate spectrum resources for municipal functions. Where appropriate, individual requests could still be considered.

This policy would make the municipal government responsible for the efficient use of its total radio spectrum resources. Then, with designs based on larger networks, greater efficiency becomes possible. The municipality retains the freedom to develop a coordinated police network in cooperation with neighboring cities, or its own coordinated public safety network, or any combination of the two. From the FCC viewpoint, the primary consideration should be efficient use of the limited radio frequency spectrum.

Finally, in order to develop coordinated plans for the future, the FCC should inform the States and local governments in the large metropolitan areas that they will, in the future, be expected to provide justification for their radio frequency needs in the form of overall projected public safety requirements for the following decade.

COMMUNICATIONS EQUIPMENT FOR THE PATROLMAN

In police communications equipment, the most immediate need, for small departments as well as large ones, is the development of inexpensive, portable voice radios that will link every patrolman to his department continuously, regardless of whether or not he is in a car. Some of the possibilities are discussed in this section. There are many possible refinements that might be useful in specialized situations. Scramblers could be used to maintain security of sensitive voice transmissions and various antijam features could protect against intentional jamming of the police radio network. Digital communications, such as teletype, could be used both to conserve radio bandwidth and to provide a permanent record of the transmissions. Recording equipment could be carried

[34] The users in the Public Safety Radio Service include police, fire, highway maintenance, forest conservation, and local government.

to record confessions and witness testimony, and to provide evidence that apprehended suspects had been properly informed of their constitutional rights.

INEXPENSIVE PORTABLE TWO-WAY RADIOS

Police officials have been unanimous in their desire for small, lightweight, inexpensive, portable two-way radios for both foot and mobile patrolmen to carry at all times. With a radio, a patrolman can always call for help and he can always be reached by his commander. The radio must work inside most buildings, on the street between tall buildings, and must not be so cumbersome as to impede his regular police actions. Furthermore, it must be inexpensive enough for a police department to assign one to every man on duty.

Experience has shown that in typical situations, hand-held two-way radios must have a power output of about 1 to 5 watts for reliable operation over limited but useful ranges (¼ mile to 2 miles). The range of the units is limited primarily by such things as obstructing walls or buildings, electrical noise from industrial equipment, low antenna heights, and the inefficient antennas of hand-held units. In order to extend the range by increasing the power of the units it would be necessary to increase greatly the size, weight, and cost of the units before even a marginal improvement in range could be detected. On the other hand, reducing the power much below the 1 to 5 watt range results in unreliable performance under many conditions.

Because of the limited range of the hand-held two-way radios, repeater stations are needed to pick up, amplify, and relay the signal from the portable radio. The two-way car radio of the patrol car could be used as a repeater for the cruiser patrolman since he would ordinarily be found close to his car. Alternatively, repeaters could be placed at fixed locations around the city, such as on top of precinct houses.

Portable two-way radios available today are far from satisfactory: they need to be lighter, less bulky, easier to operate, and less expensive. Even though existing transistorized units weigh only 2 or 3 pounds, this is too much weight, when added to the officer's gun, flashlight, night stick, and other equipment he must carry.

Furthermore, existing units are awkward to operate in emergency situations primarily because the officer must pull out the antenna and hold the radio so that the antenna is away from his body. Shirt sleeve, trouser leg, and earphone cord antennas have been developed, but they are very inefficient because of the loss resulting from shadowing by the officer's body. Furthermore, current radios often experience difficulties in communicating from the inside of buildings.

Existing radios for foot patrolmen are still too expensive. The average unit with attachments generally costs about $500 to $750. Most police departments, especially the smaller ones, cannot pay this high a price even if they are willing to tolerate the size and weight.

Existing technology appears able to provide a major contribution in portable radios for foot patrolmen. The technology of microelectronics employing integrated circuits can greatly reduce the size and cost of units and provide increased reliability. Leading manufacturers in the microelectronics industry were contacted by the Task Force. There was a consensus of opinion that microminiaturized versions of current police radios would weigh about 12 ounces and could be manufactured at a cost of between $100 and $150 in lots of 20,000 or more. This would represent a four-fifths reduction in cost and a two-thirds reduction in weight. Estimated size, weight, and power characteristics of a microminiaturized version of current portable radios are as follows:

Radio frequency power output	2 watts.
Audio power output	75 milliwatts.
Transmitter efficiency of power consumption	50 percent.
Battery weight	⅓ pound.
Total weight	¾ pound.
Cost per unit (in quantity)	$100–$150.

Although microminiaturization of present equipment designs can significantly improve equipment and reduce costs, optimized design of the total communication chain between the officer on foot and the dispatcher may well bring about even greater improvements with possibly further reductions in equipment cost and weight.

One of the first steps in optimizing the design of portable radio systems would be to compare equipment performance at the different police frequencies, including possible new allocations. It is possible that penetration of buildings and effectiveness of antennas worn on the body might make higher frequencies superior to presently used frequencies. In addition, natural and man-made noise is lower at the higher frequencies. However, foliage loss tends to increase with frequency. There may well be other factors that would dominate the choice of frequency. Table 8 summarizes the relationship between some of the performance factors and frequency.

There is very little test data available on frequency propagation characteristics in a city environment which can be used for system design. In some tests, Motorola [35] found that transmissions at about 900 MHz penetrated into tunnels better than lower frequencies now in use. These indications tend to be supported by work carried out at Bell Telephone Laboratories.[36] To clarify these issues, a test program should be conducted to perform a comparative evaluation of frequencies in the range from 150 to 3000 MHz for police communications.

If the potential of the higher frequencies were realized, it would be possible to design equipment that would be much less awkward to operate in emergency situations and that might provide much more reliable communications, particularly from the inside of buildings. This may lead to important reductions in the size and the cost of the battery, which would be important because battery weight and cost represent a large portion (perhaps as much as 40 percent) of the weight and cost of the entire microminiaturized unit.

[35] C. J. Schultz, "Is 960 Mc Suitable for Mobile Operation?"; Motorola internal paper; undated.

[36] W. Rae Young, Jr., "Comparison of Mobile Radio Transmission at 150, 450, 900, and 3,700 Mc." Bell System Technical Journal, November 1952, pp. 1068-1085.

Table 8.—Performance Factors vs. Frequency of Portable Police Radio Equipment

Frequency	Body worn antenna		Industrial and manmade noise	Foliage loss	Building penetration ability
	Gain with respect to a half-wave dipole	Body shadow loss			
150 MHz	−8 to −15 db	−8 to −9 db (trouser leg or earphone cord).	Appreciable	Uncertain	Uncertain.
450 MHz	−2 to −3 db	−8 to −9 db (trouser leg or earphone cord).	Less than at 150 MHz	More than at 150 MHz	Known to be better than 150 MHz.
960 MHz	~0 to +1 db	~0 db (head or shoulder antenna).	Less than at 450 MHz	More than at 450 MHz	Indications of being better than at 450 MHz.
2000 MHz	~0 to +3 db	~0 db (head or shoulder antenna).	Probably less than at 960 MHz	More than at 960 MHz	Uncertain.

The motorized police officer can take advantage of his powerful and reliable car radio when he is on foot away from his car by such means as:

- Making the car radio detachable so that he can carry it with him.
- Making the car receiver detachable and giving the officer a separate short-range transmitter whose signal would be rebroadcast by the car transmitter.
- Developing a simplified transceiver to communicate with a matched unit in the car connected to the two-way car radio for rebroadcasting.
- Having a car radio capable of being switched to a simple repeater mode and providing the officer with a transceiver operating on base-station frequencies.
- Developing a simple short-range signaling device that could signal the car and trigger an automatic call for help.

Each of the above techniques, discussed in appendix E, would provide the motorized patrolman with a relatively reliable means of communication when he is away from his vehicle. Each of the techniques is feasible and each has advantages and limitations discussed in appendix E.

While the desired radios both for the foot patrolman and the patrolman away from his car appear to be producible, a mass market is needed. No single police agency, not even the largest ones, represents sufficient market potential to support a microminiature component production line at the price level indicated.

The Federal Government should assume the leadership in initiating the development of these portable police radios. The possible approaches include disseminating the results of a market survey to potential suppliers, paying for a major part of the development costs, or guaranteeing the sale of an initial production run of perhaps 20,000 units.

The Government should assign to an existing operating agency the responsibility to manage this program. That agency should call on the advice of both large and small police departments, and should conduct tests and studies to establish the specifications for a family of radios. They should work with industry to solicit bids on the radios and monitor its development.

DIGITAL COMMUNICATIONS

Although voice is an indispensable mode of communications for patrol vehicles, it has a number of limitations:

- It is very wasteful of the already overcrowded radio frequency spectrum.
- It provides no protection against unauthorized interception of official police communications unless expensive scramblers are employed.
- It does not create a written record.
- It is subject to phonetic errors.
- It cannot be received by an unattended patrol car without special recording equipment.

These problems could all be alleviated by augmenting the voice radio by some form of digital communications link. This would improve the bandwidth efficiency in using the network and would also permit direct communications between a police officer and a computer—for direct inquiry regarding a stolen auto, for instance. A number of manufacturers have recently developed teleprinters suitable for installation in patrol cars. These provide security of transmission and a written copy of the message even if the car is unattended. On the other hand, any message that must be read imposes on the officer's most busy sense—vision—especially when he operates as a one-man patrol.

The teleprinter signal can be narrow-band, thereby offering a potential for much more efficient use of the available spectrum. Operational tests will show how much of that advantage is reduced by the need for redundancy of transmission to compensate for errors which result from the many nodes in received signal power that exist in urban communities. Although some transmission errors will occur while the vehicle is in motion, there are various ways to reduce the error rate. Study is needed on the best means for integrating teleprinters into the police communications system both operationally and technically. Also, studies are needed to identify the most appropriate error-reducing techniques to use. A receive-only teleprinter could receive the routine broadcast messages, such as stolen-car reports. In order to provide a two-way digital link, an encoder unit would have to be added to the teleprinter. With this capability, a patrol officer could communicate directly with an on-line computer. Receive-only teleprinters cost about $1,000 to

$2,000 each and two-way teleprinters units would cost about $3,000 to $6,000 per car.

Simple coded signal transmitting devices for field units are technically feasible. These units could be used to forward such information as availability (e.g., available, out-of-service, occupied but available) for priority assignment, using the "10-series" of codes.[37] If the number of possible coded messages is small, a simple set of switches on the control head of the car radio could code the message. The officer could flip the appropriate switch and an automatic signal on the vehicle's identification and availability would be sent to the communications center. An indicator light could stay on to remind the officer of his last report.

POTENTIAL FOR STANDARDIZATION

Standardization of police mobile equipment should contribute substantially to field efficiency. A police officer is not always in the same car with the same equipment, and he must often operate the radio equipment while his attention is elsewhere. Standardization of the controls will avoid fumbling, distraction, and errors. Standardization of such basic details as cable connections and mounting brackets will make a police department less dependent on its previous supplier in purchasing spare parts or replacement equipment. The ability to accept competitive bids should increase the chances of a lower price. Equipment standardization should be nationwide in scope since there are only a few major mobile radio suppliers and there is little practical justification for limiting standardization to a local area.

Standardization could overcome disadvantages in present police radio equipment such as the following:

Patrol cars fitted with cabling and racks for one make of equipment cannot accept equipment of another make without substantial modification.

Few parts are common among different makes of equipment, complicating the inventory problem.

Test equipment that is designed for use with one manufacturer's equipment frequently cannot be used with similar equipment made by another.

Dissimilarity of circuitry places additional training requirements upon maintenance personnel.

Dissimilarity in the way operating controls are positioned and variations in their function complicate the operational problem.

Equipment of one manufacturer is not always electronically compatible with the equipment of another. For example, the selective signaling system of one manufacturer's equipment generally will not operate another selective signaling device.

Standardization limited to items such as cable connectors, mounting hardware, and control heads could be implemented within a relatively short time and should provide very positive benefits in terms of operations and maintenance.

Thus, a program of nationwide standardization of police mobile radio equipment should be established. The standardization program should be limited to considerations of basic equipment compatibility such as the following:

Sockets and plugs.
Terminal strips and the utilization of the individual terminals.
Housing dimensions.
Mounting racks and baseplates.
Control heads.
Selective signaling techniques.
Crystals and crystal holders.

The Associated Public Safety Communications Officers (APCO) has taken the position[38] that the standardization of control heads is of fundamental importance. With APCO's encouragement, Mr. David Niblack[39] of the Colorado Highway Patrol has designed a standard radio control head. This program is described in more detail in appendix E.

Because of the complexities in extending the scope of standardization, the further possibilities should be explored and developed on the basis of experience in this limited standardization program to assure that its benefits can be obtained without having a negative effect upon manufacturers' efforts to improve their products.

[37] Associated Public Safety Communications Officers, Inc.; "APCO Public Safety Communications Procedure Manual."

[38] Personal Communication with Mr. Leslie M. Walker, Chairman, APCO Engineering and Research Committee.

[39] Niblack, D. L., "New Concepts in Mobile Control Console Design," APCO Bulletin, vol. 32, No. 9, Sept. 1966.

Chapter 4

Aspects of Court Management, Corrections, and Crime Prevention

Although the major emphasis of the Task Force's work focused on police apprehension operations, a significant effort was directed at the problem of reducing delay in processing defendants through the courts. In addition, some work was done on two aspects of corrections—the use of programed learning techniques to aid rehabilitation and the use of statistical techniques to aid both sentencing and correctional decisions—and technological aspects of crime prevention through reducing opportunities for crime—redesign of automobile components to make auto theft more difficult and street lighting. These studies are discussed in this chapter. In addition, a number of other possible applications of science and technology, which have not been studied in detail, are mentioned.

COURT OPERATIONS—REDUCING DELAY

It is a basic precept of our society that justice should not be administered with one eye on the clock and the other on the checkbook. It is often the fact, however, that justice in the United States is rationed because of the limited resources at its disposal and the inefficient way in which they are used. At the same time justice may be effectively denied because of inordinate delays between arrest and final disposition. The techniques of modern management technology can help to achieve the most efficient use of the available resources, within the limits of procedures designed to ensure the due administration of justice.

The Task Force has focused its attention on the processing of defendants through a court, with special emphasis on the reduction of delay. Various solutions to the problem of delay have been suggested by judges, lawyers, and court administrators. Whether or not any of these solutions would indeed reduce delay can only be determined after they have been put into effect. In order to make preliminary tests of some alternatives without disrupting the operating courts, the Task Force examined the feasibility of using computer simulation techniques for experimenting with various modifications in the criminal court processing system. The judicial decision making process was not a subject of this study.

Because court systems in the Nation differ in organization and procedure, no single model will serve to represent them all. The approach taken was to test the feasibility of simulating one of these systems, namely the system for processing felony defendants in the District of Columbia. The steps followed were:

(1) Describing in detail the organization and structure of the court system for processing felony defendants;

(2) Analyzing the available data on felony defendants in the U.S. District Court for the District of Columbia to determine the distribution of total time to disposition, time intervals between major events in the system, potential areas of delay and possible causes;

(3) Developing a computer simulation of the processing of felony defendants in the District of Columbia trial court system which:

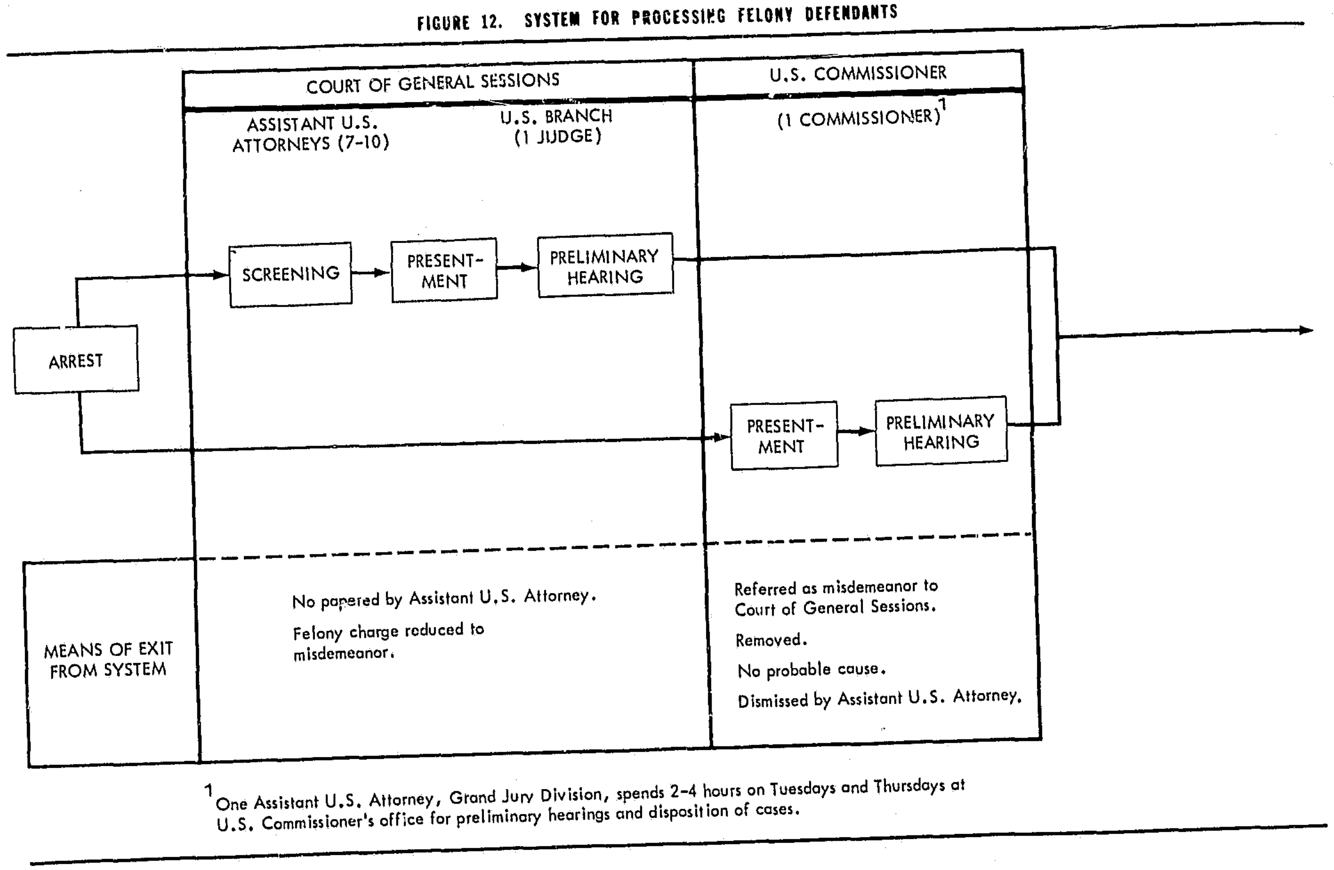
   a. Operated like that observed in the data (i.e., to produce the average time intervals between steps in the process similar to those observed in the data);

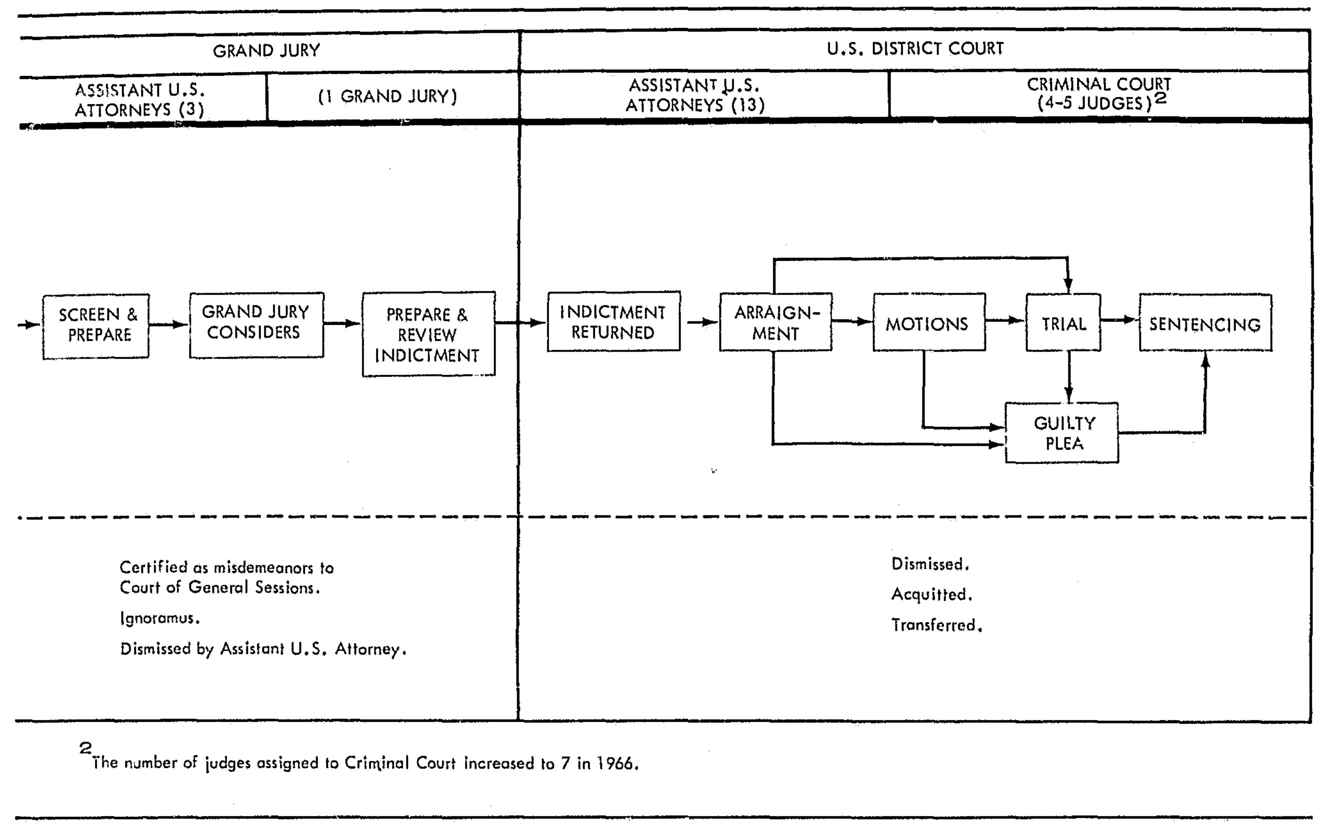
   b. Could be manipulated to investigate possible organizational or procedural changes in the system and to measure their impact on delay and on resource requirements.

THE DISTRICT OF COLUMBIA COURT SYSTEM FOR PROCESSING FELONIES

The various steps and the associated resources for processing felony defendants in the District of Columbia court system are shown in simplified form in figure 12. The first step is presentment, which occurs before a judge of the Court of General Sessions (the general jurisdiction court of first instance of the District of Columbia) or the U.S. Commissioner. Both are available for presentment and preliminary hearing in felony cases. Presentment is often preceded by a review or screening of the case by an Assistant U.S. Attorney, Court of General Sessions Division. He determines whether to reduce the felony charge to a misdemeanor, to terminate the case ("no papering"), or to proceed with prosecution.

FIGURE 12. SYSTEM FOR PROCESSING FELONY DEFENDANTS





The case is next processed in the office of the U.S. Attorney, Grand Jury Unit. It is screened again and calendared for presentation to the grand jury. The grand jury votes an indictment if there is concurrence of 12 or more of the jurors. Thereafter, the indictment is signed by the foreman and by the U.S. Attorney and returned (generally on Monday) in open court.

Arraignment is the next step. It is generally a perfunctory proceeding in which the accused appears, is advised of the formal charge and enters a plea—usually not guilty. At about this time the case is assigned to an Assistant U.S. Attorney who will probably handle it until final disposition, and a defense counsel is appointed by the court for a defendant who cannot afford counsel.

Following arraignment, trial preparation proceeds, motions are filed and heard, the case is placed on a calendar and, finally, progresses to trial. Only about 30 percent of the 1965 dispositions resulted in a trial; approximately 55 percent pleaded guilty to the offense charged or to a lesser offense prior to or during trial. The remaining 15 percent of the defendants were dismissed.

TIME DELAY IN PROCESSING FELONIES

The time delay problem was approached by analyzing in detail the data on 1,550 felony defendants whose cases commenced by filing of indictment or information in the U.S. District Court for the District of Columbia in 1965.[40] The time periods that these defendants were in the court system were compared with the timetable developed by the Commission's Administration of Justice Task Force. That timetable proposes that the period from arrest to trial of felony cases be not more than 4 months, with a maximum of 14 days from initial appearance to formal charge. The circled numbers in figure 13 show a further breakdown of maximum time periods between the various steps in the processing of felony cases as recommended by the Commission. Also included in this figure are the 50th percentile (median), 80th percentile, and 100th percentile (maximum) times observed in the 1965 District of Columbia data. Measured against the recommended timetable and evaluated in terms of best estimates of actual court and attorney time spent on consideration of a case, it can be seen that appreciable delays do exist. For example, 50 percent of the defendants who waived preliminary hearing had an elapsed time between presentment and return of indictment of greater than 42 days, whereas 20 percent had an elapsed time greater than 72 days. The maximum observed time was 269 days. From arraignment to guilty plea the elapsed time for 50 percent of the defendants exceeded 64 days, whereas 20 percent had elapsed time greater than 124 days, with a maximum observed time of 463 days. The timetable recommends a maximum of 63 days between arraignment and trial.

In summary, one-half of the defendants who pleaded guilty or were dismissed were in the court system longer than 4 months, 20 percent longer than 7 months. The defendants who went to trial took a median time of over 5 months from initial appearance to conviction or acquittal, 20 percent longer than 9 months. Contrary to generally held beliefs, motions were not the main cause of delays. Only one-half of the defendants filed one or more motions; however, one-half of these were filed more than 40 days after arraignment.

Experienced lawyers have pointed out that most of the steps in the actual processing of felony defendants require very little actual court time. The initial hearing for a defendant takes only a few minutes; a preliminary hearing usually takes between 15 and 30 minutes; a grand jury can hear, deliberate, and vote on the average case in less than 30 minutes; arraignment takes a few minutes; most motions can be heard in 10 minutes. A guilty plea requires as much court time as it takes a defendant to answer a dozen questions. The court time spent on a defendant who pleads guilty (approximately one-half of the felony defendants) probably totals less than 1 hour, yet in the District of Columbia the median time from initial appearance to disposition is 4 months. The data indicated that one-third of the time was spent waiting for return of the grand jury indictment. After arraignment on the indictment, additional time is required for the preparation of the necessary papers. But for the typical case, the actual time devoted to this process is a few days at the most, not weeks or months.

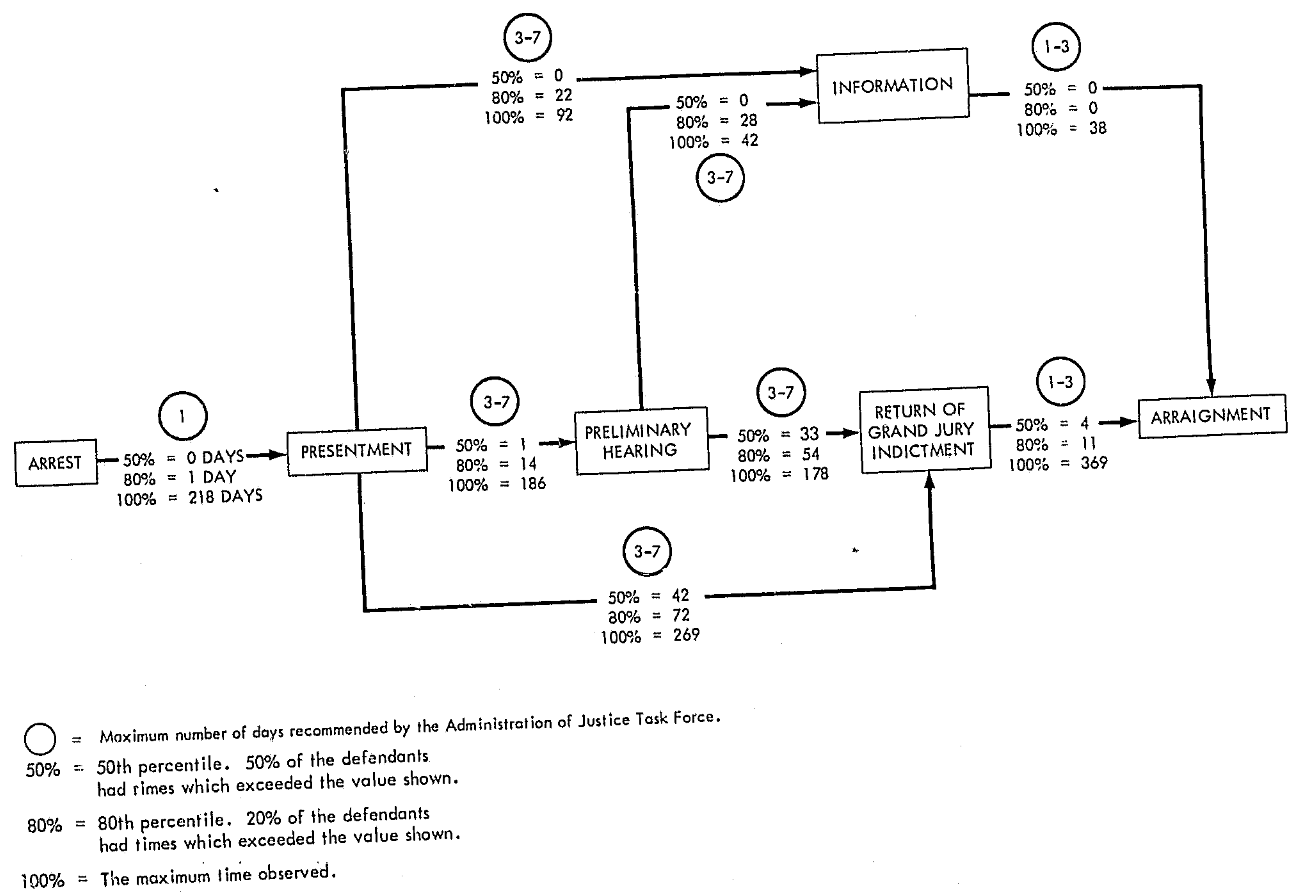
COMPUTER SIMULATION OF PROCESSING FELONY CASES

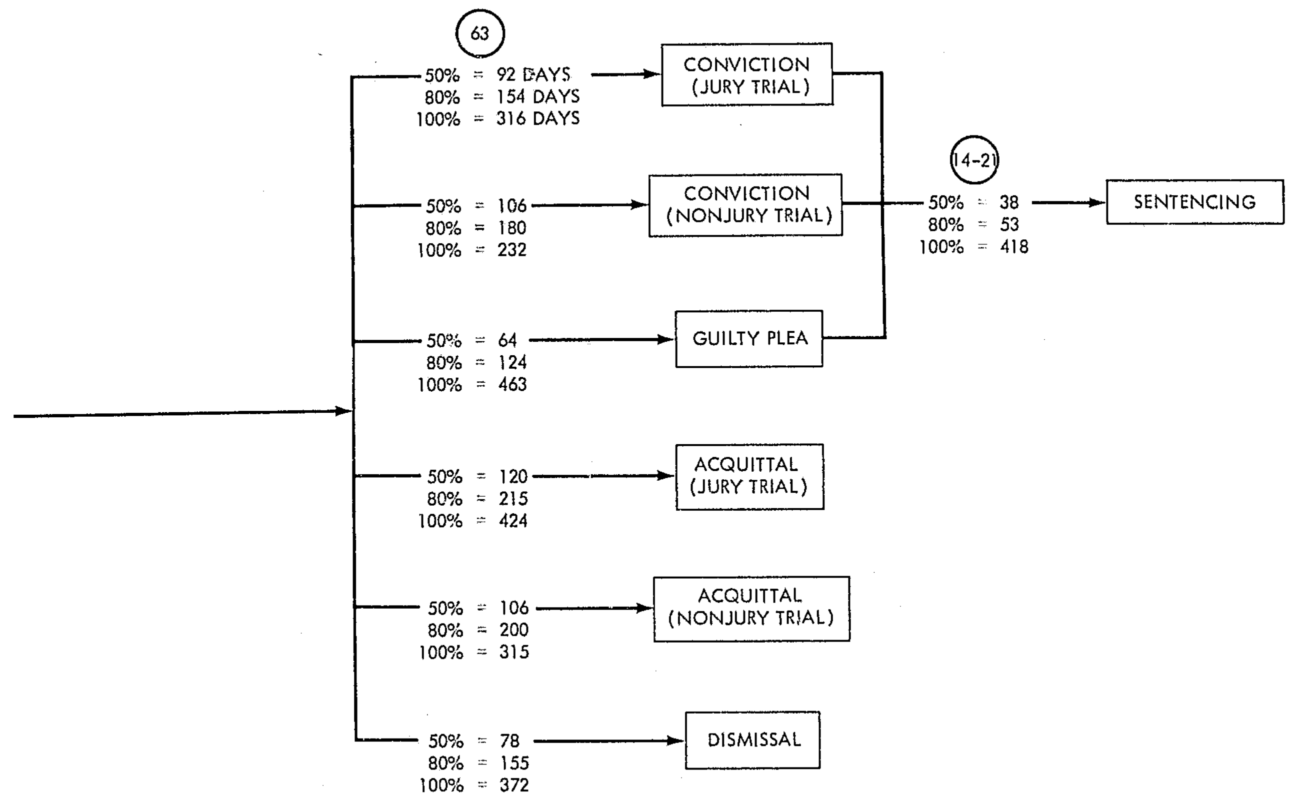
To study the impact of alternative methods of alleviating the delay in the processing of felony cases, the Task Force developed a computer simulation of the court processing activity. The simulation permitted experimentation with the court operating procedures with no disruption to the actual court operation. To make best use of the limited time available, an established simulation language was selected, IBM's General Purpose Systems Simulator (GPSS). The language, designed primarily for simulating industrial production processes, proved quite adequate to handle the court process.

The resulting model, called COURTSIM, is described more fully in appendix I. Figure 14 is a flow diagram of the process as it existed in the District of Columbia Court system. The circles represent processing units or "milestones" in the processing of a felon. For example,

[40] A more detailed description and analysis of the District of Columbia felony data is presented in appendix I.

FIGURE 13. NUMBER OF DAYS BETWEEN STEPS IN PROCESSING OF FELONY DEFENDANTS - 1965





the circle labeled PRS represents the Court of General Sessions, U.S. Branch, where the defendant makes his first appearance before the courts. The circle labeled USC represents the U.S. Commissioner, where defendants can also be presented. The arrows from one circle to another indicate the possible paths that the processing of a defendant may take; for example, from ARR (arrested) he may be presented to the U.S. Commissioner or his case may be discussed with the DAA (an Assistant U.S. Attorney, General Sessions) for possible presentment at PRS. Finally, the squares represent possible locations in the process where a defendant may exit from the system due to a dismissal, reduction of the charge to a misdemeanor, "no paper," etc.

The numbers on the arrows represent the percentage of defendants from each processing unit which take the indicated path. These percentages were estimated from the data and by staff members of the President's Commission on Crime in the District of Columbia.

COURTSIM was used to simulate the flow of the 1965 felony defendants through the District of Columbia court system. As the model is presently designed it does not handle the small percentage of cases that require exceptionally long times between events in the system; these could be incorporated into a later version.

The results of several of the simulation runs are presented in table 9 with a summary of a few of the more important time intervals starting from presentment of the defendant. The first row presents the median times from the 1965 District of Columbia data. The last row presents the recommended timetable of the Administration of Justice Task Force. The other rows contain the times generated by computer simulation runs.

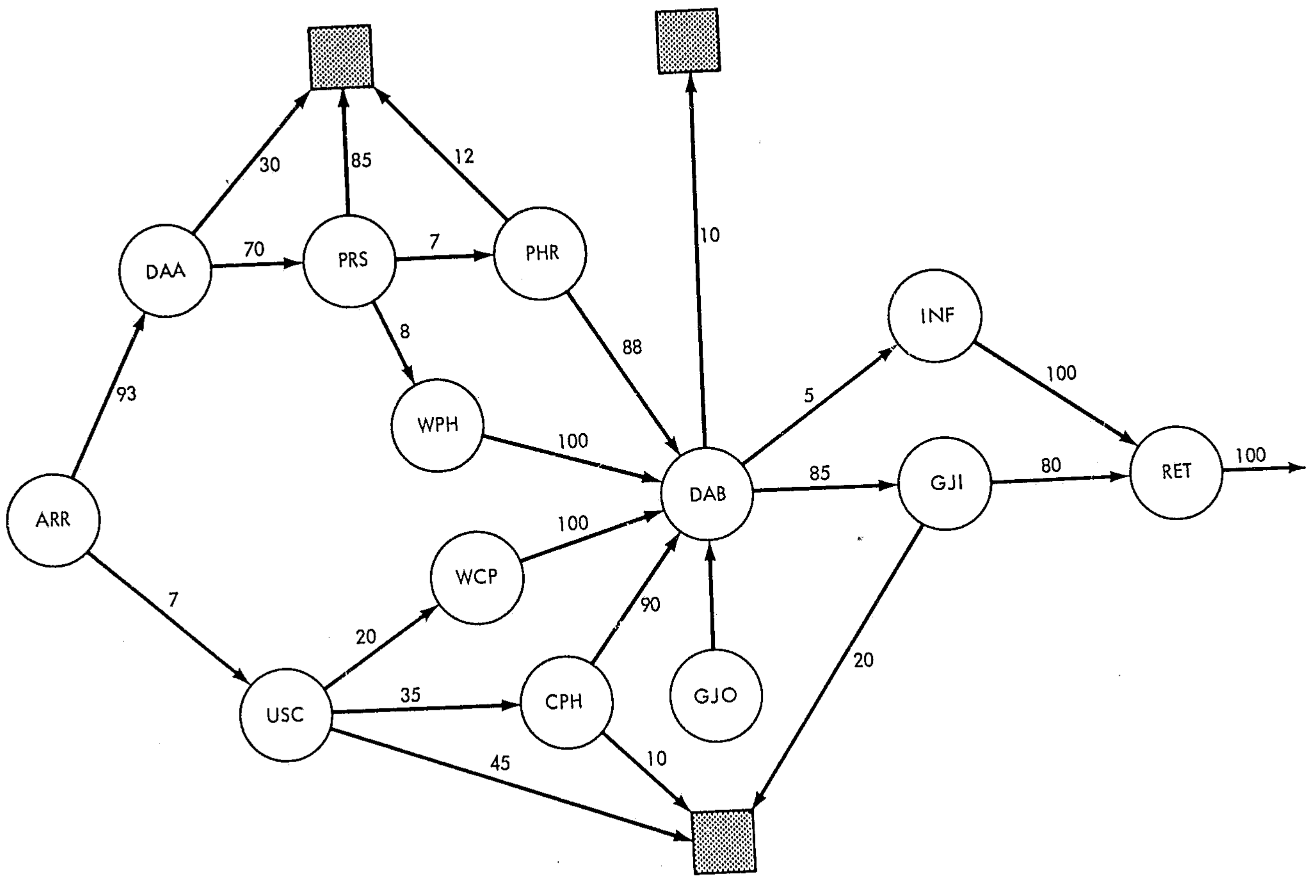
The second row is a time summary of the simulation using the conditions in 1965. In 1965, one grand jury was sitting and an average of five district court judges were assigned to the criminal part of the court. Under these conditions, the simulation reflected the actual court operation. In both there was an average time of approximately 6 weeks between initial presentment and the return of an indictment, and an average of at least 13 weeks from

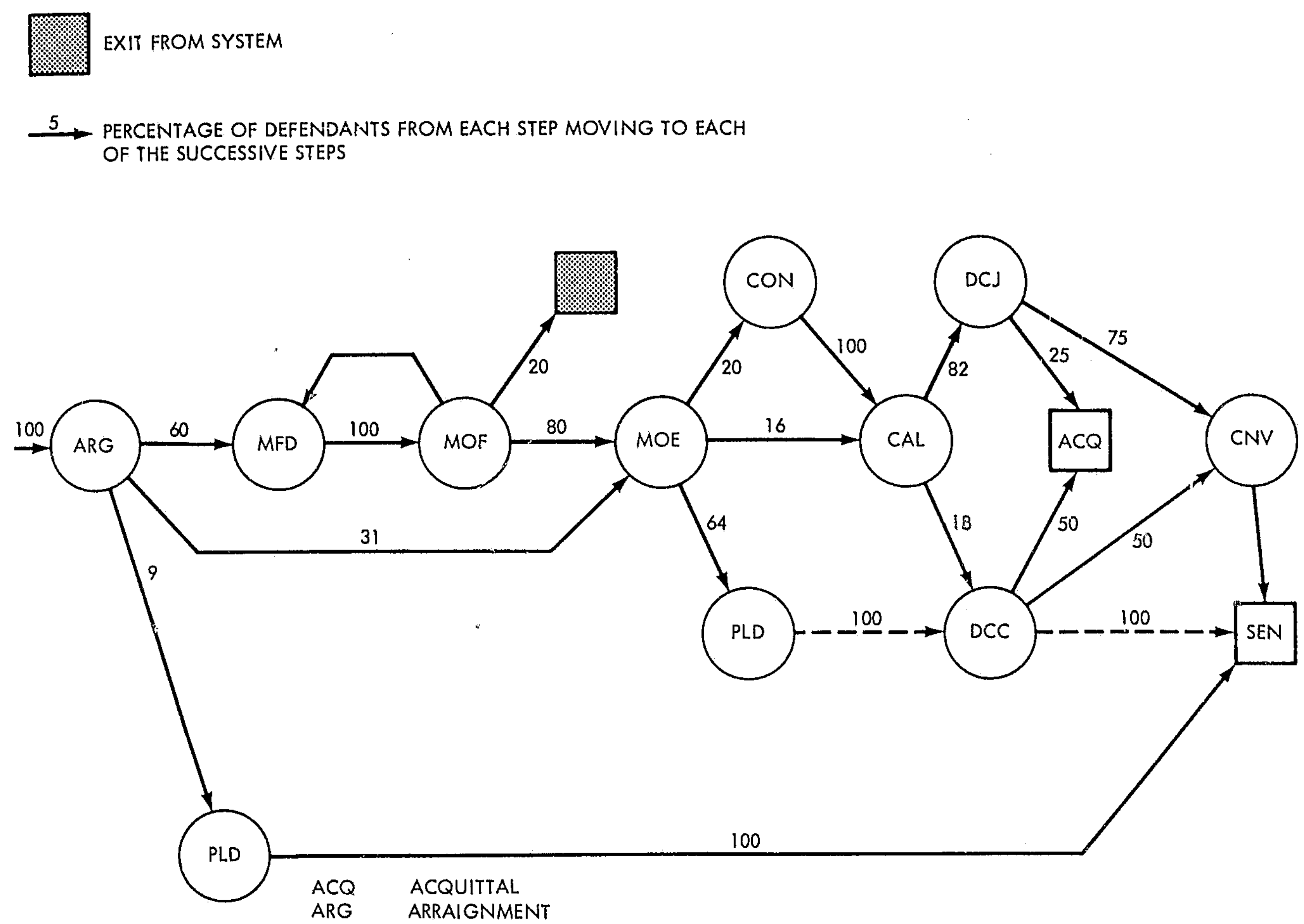
Table 9.—Representative Felony Processing Times in Days

COURTSIM run	Presentment to						
	Return of indictment	Arraignment	Guilty plea	Dismissal	End of motions [1]	Ready for trial	Time in queue at grand jury unit
1965 data (median days)	40	53	107	134	148	[3] 167	?
1965 basic [4]	47	54	116	122	152	160	36
1965 basic with grand jury queue eliminated	16	24	90	102	----	127	8
1965 basic with grand jury queue eliminated and zero transit times	6	8	48	14	----	56	<1
1965 basic with all cases processed through U.S. Commissioner	61	64	131	140	----	164	45
1965 basic with rule 87; guilty pleas at 30 percent	38	40	68	58	70	88	31
1965 basic with rule 87; eliminated queue at grand jury	7	9	37	27	39	57	<1
Administration of Justice Task Force model timetable (maximum days)	14	17	80	----	[2] 55	80	----

[1] Cases with at least one motion. [2] First motion decided. [3] To trial date. [4] The mean number of days is used in rows 2-7.

FIGURE 14. FLOW DIAGRAM OF COURT SIMULATION





ARR	ARREST
CPH	PRELIMINARY HEARING AT U.S. COMMISSIONER
DAA	ASSISTANT U.S. ATTORNEY, COURT OF GENERAL SESSIONS
DAB	ASSISTANT U.S. ATTORNEY, GRAND JURY DIVISION
GJI	GRAND JURY INDICTMENT
GJO	GRAND JURY ORIGINALS
INF	INFORMATION
PHR	PRELIMINARY HEARING AT U.S. BRANCH, COURT OF GENERAL SESSIONS
PRS	PRESENTMENT AT U.S. BRANCH, COURT OF GENERAL SESSIONS
RET	RETURN OF GRAND JURY INDICTMENT OR FILING OF INFORMATION
USC	PRESENTMENT AT U.S. COMMISSIONER
WCP	WAIVED PRELIMINARY HEARING AT U.S. COMMISSIONER
WPH	WAIVED PRELIMINARY HEARING AT U.S. BRANCH, COURT OF GENERAL SESSIONS

ACQ	ACQUITTAL
ARG	ARRAIGNMENT
CAL	CALENDAR
CNV	CONVICTION
CON	CONTINUANCE
DCC	NONJURY TRIAL
DCJ	JURY TRIAL
MFD	MOTION FILING
MOE	MOTIONS ENDED
MOF	MOTION HEARD
PLD	GUILTY PLEA
SEN	SENTENCING

arraignment to beginning of trial. The close correspondence between the actual and the simulated times suggests that the model is a valid representation of actual operations.

The simulation indicated that most of the time prior to arraignment was spent in the Grand Jury Unit awaiting return of indictment (5 out of 7 weeks). By simulating the system with a second grand jury sitting part of the time, the time spent in the Grand Jury Unit was reduced from 5 weeks to less than 1 week, resulting in a time of approximately 2 weeks from initial presentment to return of the indictment. This is shown in line 3 of table 9. Thus, it appears that for a cost of probably less than $50,000 per year for the additional grand jury and associated support resources, the delay from presentment to return of indictment could be reduced by 70 percent. The total time until the defendant is ready for trial would be reduced from 160 days to 127 days.

The fourth row gives a lower bound on the average times if, in addition, all transit times were eliminated, i.e., as soon as one processing stage finishes with a defendant, he proceeds immediately to the next and waits only if the next processor is unavailable because of weekends or he is busy. If such a condition had existed in the District of Columbia courts in 1965, a defendant would take an average of approximately 2 months after presentment to be ready for trial. Comparing these times with that of the last row (the Administration of Justice Task Force recommended maximums), one can see that the timetable appears to be reasonable.

An organizational change was next examined, namely the preliminary processing of all defendants was done by the U.S. Commissioner (instead of by both the Commissioner and the U.S. Branch, Court of General Sessions). The results of this run (row 5) indicate that the workload on the Commissioner was not excessive and that the time from presentment to return of indictment was not significantly increased.

An additional example of the use of the simulation is in examination of the possible consequences of changes in defendants' behavior resulting from changes in court procedure. Accordingly, the inputs to COURTSIM were modified to reflect some of these procedural changes and potential effects. These modifications include such factors as (1) a decreased number of defendants pleading guilty, a possible result of the Bail Reform and the Criminal Justice Acts; (2) a delay in the entry of a guilty plea; and (3) the amendment of rule 87.[41] In addition, the current calendaring system was incorporated under which cases are scheduled for trial with priorities given to jailed defendants and old cases. The 1965 workload, in terms of number of defendants and their general flow through the system, was used in these simulations. Rows 6 and 7 show the average times with one grand jury sitting regularly and with an additional grand jury sitting when necessary (to keep the average waiting time in the grand jury unit under 1 day). The results of these runs of the simulation indicate that by requiring motions to be filed and heard according to rule 87 and increasing the grand jury resources, the average time from arraignment to ready for trial was halved from 15 weeks (Row 2) to approximately 7 (Row 7). The average time from initial presentment to ready for trial was 57 days or approximately 2 months. Adding 1 month for the time from ready for trial to sentencing suggests that, on the average, the overall processing times would be less than 3 months as opposed to the 6 months (160 days plus 1 month). The time to guilty plea or dismissal is similarly reduced significantly, as is shown in those columns.

The above analyses indicate that the timetable of the Administration of Justice Task Force is practical. More generally, simulation appears to be an effective tool for examining reallocation of existing resources or efficient allocation of additional resources.

A critical factor in the above simulation runs was the required versus the available processing times associated with each step of the process (e.g., indictment, trial). Since data were generally not available, these times had to be estimated from direct observations and from officers of the court. The estimates appear to be reasonably accurate for the simulation to reflect the actual system in all the stages of the process up to trial. Although the estimates of the required and available trial times were based on the best available data as described in detail in appendix I, they may be optimistic. Further analysis of available and required trial times is required in order to investigate the sensitivity of the results to deviations in the estimated times used in the above simulations.

An important immeasurable factor not accounted for is the effect of changes in processing on the actions of defendants and court officials. The human in the system adapts to his environment and any changes made to it. The model assumes the various changes made will not affect the feedback process. For this reason, before any changes can be seriously proposed, the results of the simulation must first be thoroughly analyzed and discussed in detail with the court officers.

The major conclusion of this study is that simulation of the court process is indeed feasible, and properly used, can be a useful tool to the administrator of a court. The development and use of such a tool requires the collection of the relevant data. The simulation techniques developed here should be extended to several large urban areas as pilot studies with Federal support to determine their applicability to other court systems and to develop them in further detail.

OTHER POSSIBLE APPLICATIONS

There are a number of other areas in which science and technology appears to be applicable to court operations. Although the Task Force did not explore these in detail, they appear to warrant further examination. Some of these are summarized below.

As new instrumentation techniques, such as voice prints and neutron activation analysis, are developed, objective laboratory tests can be undertaken to test their validity and to provide guidance in evaluating testimony based on them. This can take place in laboratories apart from specific court cases rather than only waiting for the accumulation of case by case decisions.

Modern techniques of recording, such as magnetic tape, TV recording, and computer transcription of stenographic records might provide rapid and possibly inexpensive records of courtroom proceedings.

Many decisions made by appellate judges can have far-reaching ramifications on operations throughout the criminal justice system. Competent collection and analysis of data relevant to these decisions can help the judges weigh the impact of these decisions on criminal justice operations.

In court management, improved scheduling procedures might be useful in assigning court resources to cases. More efficient communications might help in handling the logistics of individual cases by bringing together the necessary resources at the appropriate time and place. Electronic calling systems, for example, could be provided to witnesses for impending cases so that they could be called on short notice even if inaccessible by telephone.

Clerical improvements in court administration, such as improved docketing systems, redesign of forms, use of simple computers, and other matters of basic business practice could improve court efficiency.

CORRECTIONS—PROGRAMED LEARNING AND STATISTICAL AIDS TO DECISIONS

One of the important objectives of the criminal justice system is the rehabilitation of identified offenders. But the pursuit of this objective has met with only limited success. Most arrests are of people who have previously been arrested. The FBI reports[43] that 75 percent of the fingerprints sent them by police departments are already in their criminal files. Of these people who have been to prison, over 30 percent return for another term.

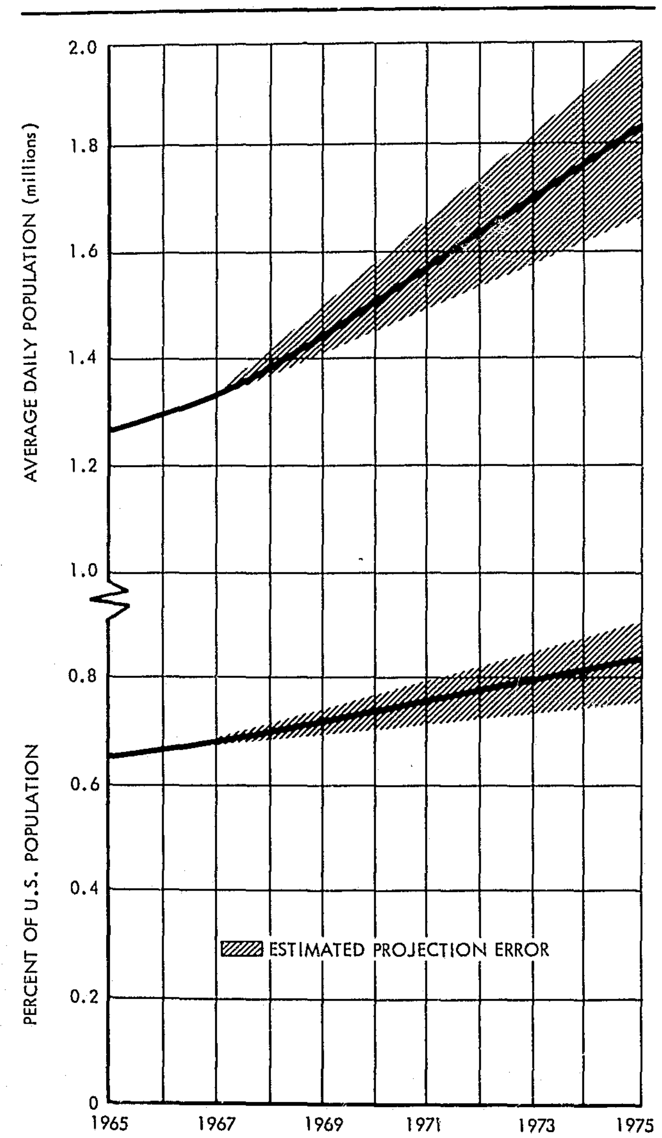
[41] Amended rule 87 of the U.S. District Court for the District of Columbia which became effective October 1966 provides that motions are to be filed within 10 days of arraignment and heard the second Friday thereafter; arraignments are to be held the second Friday after the return of the indictment.

[43] *Law Enforcement Bulletin*; February 1967; p. 24.

A major source of the problem is the sheer number of offenders corrections agencies must treat with their limited resources in funds and trained manpower. In 1966 there were about 1.3 million people under correctional supervision on any given day. Projections developed by the Task Force and shown in figure 15 estimate that there will be over 1.8 milion people under correctional supervision by 1975.[44]

Corrections involves both rehabilitating and maintaining custody of offenders. There are two elements of custody—maintaining the well-being of prisoners and preventing their escape. The problems of maintenance are very similar to those of operating any large residential institution.

FIGURE 15. PROJECTIONS OF U.S. CORRECTIONAL POPULATION, 1967-75



A full spectrum of techniques is available to assist in preventing escape. Security technology can find many uses in prisons. Electrically controlled locks, doors, ramps, and walks can be used. Closed-circuit TV cameras, remotely trainable, can scan hallways and other general areas. Electric eyes, pressure devices, and other alarm sensors, can detect the presence of persons, especially in perimeter areas. Alarm sensors could be used to replace a fixed guard post, which costs about $30,000 a year to man continuously. The design of modern prisons, built around a variety of correctional programs and organized to facilitate rehabilitation rather than merely providing facilities for eating, sleeping, and exercising, is an important challenge that modern architecture is beginning to meet.

There has also been discussion concerning uses of technology in maintaining security in community treatment programs, which are receiving increasing emphasis in corrections. Innovations of this sort might make it possible for larger numbers of offenders to be safely placed in the community. For example, it would be technically feasible to imprint the hands of some habitual check forgers with a mark, designed to wear off after a specified time, visible only under ultraviolet lamps kept in banks. It is not always clear, however, that the net effect of such techniques would be to help rehabilitation and reduce recidivism. Furthermore, their availability raises grave questions about their social value, and there is doubt whether any of them would be acceptable in a free society. As with many technological devices that raise such value questions, decisions whether or not to use them, even experimentally, must be carefully weighed.

Because of the inherently behavioral aspects of most rehabilitation problems, these did not receive major attention by the Task Force. The Task Force did, however, look into one area of education technology, programed learning, to assess its potential to contribute to rehabilitation by improving academic and vocational skills.

On a broader level, the Task Force also looked into the contributions which modern information technology could make to corrections operations. The many decisions which overlay the correctional process require, in addition to experienced judgment, information regarding the likely consequences of alternative decisions. This information should be based on careful collection of data, processed to make it available in a usable form. The timely and complete information from the integrated information systems discussed in chapter 6 would make an important contribution to improved decisions.

Data fed into the computers of an information system could be rendered more reliable and valuable by using modern statistical techniques of experiment design, and the output could be made more meaningful and useful by using appropriate techniques of multivariate statistical data analysis. Some of these techniques are briefly discussed below.

[44] The bases for these projections are set forth in app. B of the Corrections Task Force report. In general they assume that national trends in arrests, convictions and release rates will continue. Data with respect to trends in sentencing to probation or institutions are not available on a nationwide basis, however, and the projections use California data for this calculation. California has put particular emphasis on increasing the use of probation. While such emphasis is likely to spread to other jurisdictions over the next decade, the use of California data probably results in some overestimation of the number of persons who will be on probation and underestimation of the number of persons who will be in institutions and on parole. Moreover since probation terms average somewhat longer than institutional terms, use of the California data also probably results in an overestimate of the total number of persons who will be under correctional authority in 1975. If sentencing trends had been held constant in the projection, the estimated total correctional population in 1975 would be about 7 percent lower than that shown in fig. 15 and the estimated percentage of the U.S. population that this represents reduced accordingly.

PROGRAMED INSTRUCTION TO AID REHABILITATION

The great bulk of crime and delinquency in the United States is committed by males in an age group extending from the middle teens to the early twenties. In 1965, the group from 15 through 21 accounted for over one-quarter of the arrests reported in the FBI's "Uniform Crime Reports", and over one-third of the arrests for offenses other than drunkenness. Most of these individuals begin their criminal or delinquency careers while still juveniles.

Many delinquent careers are associated with failure in school. It is a short route from academic failure to dropping out of school, to idleness and unemployment, and then entry into a spiraling criminal career. Some dropouts fail because they cannot adapt to a classroom social situation. Were there some alternative way of educating them, they might find a rewarding place in the community and refrain from crime.

The populations treated in correctional programs are usually composed of individuals in their late teens or early twenties. Although they are generally not particularly deficient in basic intelligence, most of them are at an educational level somewhere in grade school.[45] Many are ripe for rapid advancement through the next few grade levels if the proper means could be found.

Few of those leaving correctional institutions, including those leaving juvenile reformatories, return to school. One of their principal needs is for the steady income of a secure job. From society's point of view, there is no better way for them to obtain their livelihood. The opportunity to upgrade these people may exist only while they are in the correctional system, an average time of less than 2 years. Thus, if they are to be significantly helped, they must make up lost years of education in a matter of months.

Programed learning seems to offer one way to help do this. It is currently being conducted with published booklets in at least two correctional institutions and experimentally with computers at several research centers. The basic technique of programed instruction is that of breaking the learning process down into a number of specific steps to be completed by the student, with immediate reinforcement contingent upon successful completion. The steps may be large or small, depending upon how much the student can reasonably negotiate.[46]

The student works through the educational material on his own, testing his understanding at frequent intervals. Whenever his responses exhibit lack of comprehension, he is diverted back to correct his deficiency. He works at his own pace, he checks his own performance, and he can do most of this alone. The methods of programed instruction are geared toward having the particular student achieve a desired level of competence in a given section of knowledge at a rate compatible with his individual capacity to learn. A learning program is completed only when the individual student is brought up to the desired level of competence.

Experiments with high school students suggest that such teaching techniques may be particularly effective in improving the learning of students whose motivation to learn in ordinary classroom situations has been destroyed by years of failure. This expectation has been borne out by the experience with programed instruction at Job Corps centers throughout the Nation. Since the population of correctional institutions is largely composed of individuals with such a history of failure experience, it would appear that programed instruction is particularly appropriate for them.

Several correctional institutions have begun pilot projects which involve academic programed instruction. At the CASE experiment at the National Training School for Boys in Washington, D.C., programed instruction was part of an experimental attempt to establish reasonable behavior patterns by rewarding good behavior by subjects under continuous supervision.[47] During the program's 2 years, it showed considerable success. Over 90 percent of the boys involved achieved an academic upgrading exceeding 4 school years during the first 6 months of 1966.

For the past 4 years, the Rehabilitation Research Foundation at the Draper Correctional Institute,[48] in Elmore, Ala., has been conducting an academic educational project using programed materials almost exclusively, with an occasional lecture by a guest speaker. The academic instruction at Draper covers more than 350 courses, ranging from literacy training to college preparatory work.[49] Students spend 35 hours a week on their academic courses and have found that only 1 percent of the students fell below the 85-percent requirement on final mastery tests.

In addition, for the past 2 years vocational training programs have been conducted at Draper using programed learning aids. The programs have been integrated into vocational courses covering barbering, bricklaying, welding, electrical appliance repair, radio-television repair, automobile servicing, and technical writing. These courses were set up to correspond to job placement potentialities in the vicinity of Elmore. The learning programs used in these vocational courses were developed and written by the Rehabilitation Research Foundation at Draper. As of early 1966, over 25 vocational booklets were either published or in preparation. The entire vocational training program at Draper costs slightly less than $1 per student hour. This includes the cost of vocational instruction, counseling services, and the cost of developing, writing, and publishing the programs.

The introduction of computer assistance in programed instruction courses has potential for handling many more students with more complex programs. Their present costs are somewhat greater than the manual techniques. The IBM Instructional 1500 series rental costs are in the order of $1.50 to $2 per student hour. The cost of constructing a computer instructional program is presently estimated to run from $2,000 to $6,000 per instructional hour. It can cost as much as $10,000 per hour of instruction to write, test, and revise a good computer instructional program, and may take as long as 3 or 4 years to do a good job. Some of these costs are likely to decline in future years.

[45] The juvenile first-offender population contains the full range from the feeble-minded to the genius, with mean I.Q. in the lower part of the normal range. For example, the average I.Q. of 100 boys and 100 girls in training schools in Iowa in 1955 was 90.4 for the delinquent boys and 94.1 for the delinquent girls. Delinquent boys are usually 2 to 4 years or more retarded in school level. See W. A. Lunden. Statistics on Delinquents and Delinquency, Thomas Publishing, Springfield, Ill., (1964, pp. 81, 88).

[46] Gilbert, Thomas F., Mathetics, the Technology of Education, "Journal of Mathetics," 1–25, (January 1962).

[47] Cohen, H. C., Filipczak, V. A., and Bis, V. S., "Contingencies Applicable to Special Education of Delinquents: Establishing 24-hour Control in an Experimental Cottage," Institute for Behavioral Research, Silver Spring, Md., 1966.

[48] Draper is one of three maximum security institutions in Alabama.

[49] Egeiton, John, Where They Try to Make Winners Out of Men Who Have Always Lost, "Southern Education Report," May–June 1966.

In one study at Draper Correctional Center, it was found that the students completed 1 academic year of school work per 200 hours of work with programed learning materials. The average cost per academic year of advancement was therefore well under $400. Based on the expected contribution of each year's schooling to future earnings,[50] the discounted future taxes from that year's schooling is about $800. This, alone, is more than enough to cover the cost of education, without considering the thousands of dollars of criminal-career costs saved, and, most important, the improved chance of a fuller life for the individuals involved.

About 70 percent of the first class of graduates from the Draper vocational school were men who had previously been jailed, released, and jailed again. In its first 2 years, 78 youthful offenders were graduated from this school, paroled and placed in jobs. Only four of them were returned to prison for commiting new crimes and six for technical violations of parole conditions.[51] Compared to the usually quoted one-third to two-thirds rate of return to prison,[52] a return rate of between one-seventh to one-eighth looks very good indeed. However, these figures represent the result of only a preliminary field test of programed aids to vocational instruction. Much more careful and thorough experimentation, including a sample with a longer exposure time and comparisons to equivalent "control" groups, are needed before any definite conclusions concerning the amount of recidivism reduction can be drawn.

Programed learning appears to have significant advantages for educating the identified problem children who find their way into correctional institutions, and potentially also for crime-prone populations in the community. Its use should be encouraged, and further evaluated in controlled circumstances, using conventional teachers, or even fellow inmates, for supervision.

On the basis of the foregoing considerations, it appears desirable for more correctional institutions to initiate vocational and academic programs with programed instruction. Using booklet-type programed materials, one or two permanent staff members should be able to handle teaching loads in excess of 100. Part-time assistance for monitoring and informal tutoring can frequently be obtained from students in local colleges or universities. Faculty members of local schools or colleges can be contacted to provide supplementary lectures when appropriate.

Pilot projects should be established at selected institutions to assess the feasibility and practicality of computer assistance to both the academic and the vocational programs in a correctional setting. The institution selected should also have conventional classroom and booklet-type programed learning courses in operation simultaneously with the computer project, in order to provide a basis for a carefully controlled comparison. Careful records should be kept on the costs of each project, on the rate of achievement of students in each, and on significant features or peculiarities of each method. Student reactions should be solicited and noted. Post-institutional followup of students in each group should measure both recidivism and vocational progress.

STATISTICAL TECHNIQUES TO AID DECISIONS

There are many decisions which must be made in the operation of a correctional system for which statistical estimations of an individual's probable future behavior are necessary. In deciding on probation or parole, information concerning the likelihood of the individual returning to crime is essential. In assigning a security classification, information concerning the reliability or trustworthiness of the individual is needed. In selecting a correctional program for an individual, an estimate is needed of the expected effects of each of the various programs on the recidivism and general rehabilitation of such an individual.

Just as important as the evaluation of the individuals being treated in a correctional system is the objective evaluation of the treatments themselves. The program managers must decide what kinds of treatment programs should be made available and to whom they should be applied. Yet, despite both the pressing need and the ready opportunity, the application of sound scientific methods in the field of corrections has been very slow in coming.[53]

Most of the information presently available bearing upon questions such as these is in either of two forms. First, there are many "rules of thumb" which have evolved out of experience and are justified or rationalized in large part on the basis of anecdotal histories of operations. Second, there are many statistical tabulations of operations in which there was neither a control group nor an adequate characterization of the experimental group.

In recent years, though, controlled correctional experimentation has become somewhat more widely employed. One example is the California Youth Authority's community treatment project,[54] in which an experimental group was given community treatment and a control group was treated in an institution. Here an attempt was made to relate the parole revocation probability to type of treatment and to individual personality characteristics. Significant differences were found between the two treatments, and the difference varied strongly with the personality type.[55] The experimental group was found to have only 60 percent as many parole revocations as the control group. Two of the six social types,[56] however, fared better under the institutional program, though the difference was not significant. Although the results of this particular project are highly tentative, it does represent the beginning of a much needed effort to correlate both individual characteristics and type of treatment to subsequent commission of crimes, rearrests, reconvictions and recommitments.

Statistical analyses of large numbers of criminal-career histories will be required to provide these needed correlations. Statistical aids for helping in sentencing and selection of proper treatment of individuals under correctional supervision should be developed.

A wide range of techniques of statistical analysis are available, which one is relevant being dependent upon

[50] Based on data from "Statistical Abstract of the United States, 1966;" Department of Commerce; Government Printing Office; Washington, D.C.; 1966; p. 339.

[51] McKee, John, Donna M. Seay, and Anne Adams, "Eighth Progress Report, Expt. and Demonstration Project for Training and Placement of Youthful Offenders," Draper Correctional Center, Elmore, Ala., Nov. 1, 1965–Feb. 1, 1966, p. 24.

[52] Glaser, Daniel, "The Effectiveness of a Prison and Parole System," Bobbs-Merrill & Co., N.Y., 1964.

[53] Glaser, Daniel, Scientific Evidence on the Prison Potential, "Proceedings of the Ninety-First Annual Congress of Corrections," Am. Corr. Assoc., New York, 1961, pp. 134–49.

[54] California Youth Authority (H. G. Stark, Director), Community Treatment Project: Research Report No. 6, 1965.

[55] The personality types were: Asocial-aggressive, conformist-immature, conformist-cultural, neurotic-acting out, neurotic-anxious, and manipulator.

[56] Neurotic-anxious and manipulator.

the nature of the specific problem under consideration.[57]

Various forms of multivariate statistical analysis [58] can be used. Multiple discriminant analysis,[59] employing regression estimation techniques,[60] can be used in cases where the events to be predicted are in discrete categories (e.g., types of crimes), rather than along some naturally ordered continuum (e.g., arrest rate).

In addition to assisting in treatment selection, statistical techniques of experiment design must play an important role in correctional program development, testing, evaluation, and planning. Of all the behavioral areas, offender rehabilitation offers perhaps the best opportunity for reasonably careful experimental control to determine the effects of actions taken. There should be an expanded use of careful, controlled evaluation in the development of correctional programs. Program development should be preceded by careful studies of the specific correctional objectives, and testing should be conducted by personnel qualified in the behavioral sciences and in statistical analysis.

REDUCING OPPORTUNITY FOR CRIME—AUTO THEFT AND STREET LIGHTING

The problem of crime prevention is an extremely complex issue that ultimately requires dealing with the diverse causes of crime. The most basic means of preventing crime is by reducing the need or desire of potential offenders to engage in criminal activity. This can be accomplished by helping them individually through providing fuller employment, better education, and personal counseling and therapy when needed. Even more fundamentally, it can be addressed by reducing the many socio-economic causes of crime through programs which have objectives much broader than crime control alone. Those basic problems were outside the scope of the work of the Task Force. There are, however, a number of more immediate ways in which technology can address specific problems in crime prevention.

The criminal justice system itself prevents crime by posing a threat of apprehension and a risk of consequent punishment; by temporarily incapacitating criminals, especially potential repeaters, generally through incarceration; and by rehabilitating past offenders. The focus in this section is on means outside the criminal justice system for crime prevention.

Technology is directly applicable to reducing criminal opportunities through protecting or "hardening" targets of crime, by making them less vulnerable to theft and by inhibiting criminal activity. Homes and valuables can be protected by better safes and locks; magnetic inks can be used to curtail the use of bogus checks; photographs on credit cards would reduce improper use; eventually, store owners will be able to establish immediate identity and sufficiency of credit with the aid of electronic data processing.

The automobile is a common target of theft which is particularly susceptible to devices of hardening. It accounts for about one-third of the part I crimes in the United States: Auto theft, larceny of auto accessories, and larceny from autos each represent about 11 percent of part I crimes. Design changes in automobiles making accesories such as hub caps, seats, radios and batteries less easily removed, could reduce the illegal traffic in these items.

In addition to hardening the target, the environment can be made less conducive to crime. Criminals can be inhibited by increasing the probability that their illegal activity will be detected. Many kinds of sensors and alarms, discussed in chapter 2, are available to discourage intrusion into unattended premises. Closed-circuit TV could be used to maintain continuous surveillance of trafficked areas. Bogus check passers can be discouraged by a camera that photographs all check cashers. People subject to a high risk of robbery, such as liquor merchants, gas station attendants, and bank clerks, could carry concealed radio transmitters by which they could trigger an alarm.

Clearly there are many means by which technology can be applied to reduce criminal opportunities. Two of these, automobile design modification as an example of target hardening, and street lighting as an example of an inhibitor, are discussed below.

INCREASING THE DIFFICULTY OF AUTO THEFT

Auto theft is prevalent and costly. In 1965, 486,000 autos valued at over $500 million were stolen. About 28 percent of the inhabitants of Federal prisons are there as a result of conviction of interstate auto theft under the Dyer Act. In California alone, auto thefts cost the criminal justice system over $60 million yearly.

The great majority of auto theft is for temporary use rather than resale, as evidenced by the fact that 88 percent of autos stolen in 1965 were recovered. In Los Angeles, 64 percent of stolen autos that were recovered were found within 2 days and about 80 percent within a week.[61] Chicago reports [62] that 71 percent of the recovered autos were found within 4 miles of the point of theft. Data from Berkeley [63] showed that 82 percent of the recovered autos were found in Berkeley or in police jurisdictions contiguous to it. The FBI estimates that 8 percent of stolen cars are taken for the purpose of stripping them for parts, 12 percent for resale, and 5 percent for use in another crime.[64]

Auto thefts are primarily juvenile acts. Although only 21 percent [65] of all arrests for nontraffic offenses in 1965 were of individuals under 18 years of age, 63 percent of auto theft arrests were of persons under 18. Auto theft represents the start of many criminal careers; in an FBI sample of juvenile auto theft offenders, 41 percent had no prior arrest record.

The theft may come about simply because a boy sees an unlocked automobile readily available. Berkeley, Calif.,[66] reports that 49 percent of the autos stolen in 1965 had a key left in the ignition or the ignition open. Milwaukee, Wis.,[67] reports that 37 percent of the autos stolen had the ignition open or a key in the ignition. The FBI reports that, nationwide, 42 percent of the autos stolen had the key in the ignition or the ignition unlocked. Even of those taken when the keys were out, at least 20 percent are stolen by merely shorting the ignition with tools as simple as jumper wires, paper clips, tinfoil, and coins.

The effects of changing the ignition system to make theft more difficult were studied on the basis of St. Louis experience. Figure 16 shows by make and model year the number of cars reported stolen in St. Louis in the first 8 months of 1966. The Chevrolet was the most frequently stolen car, well out of proportion to its registration for models prior to 1965. Figure 16 also shows the ratio of these numbers of stolen cars to Missouri registration totals, i.e., the probability, by make and model, of a car registered in Missouri having been stolen in 1966. The sharp drop in theft probabilities of the 1965 and 1966 models indicates that the change in the Chevrolet lock (eliminating the unlocked "off" position) in 1965, resulted in about 50 percent fewer 1965 Chevrolets stolen than the previous year's models. A similar effect occurred for Buick theft probabilities, due to a similar ignition change. The increase in thefts of the other makes was overshadowed by the decrease in Chevrolet and Buick thefts. Thus, the 1965 Chevrolet and Buick owners in 1965 and after had more protection than the owners of previous years' models.

These findings suggest that the easy opportunity to take a car may contribute significantly to auto theft and that thefts by the relatively casual or marginal offender would be reduced by making theft more difficult than merely starting the car. Educational campaigns advising drivers to remove their ignition keys and to lock their cars are important, but their effects are difficult to sustain.[68] Some cities have ordinances imposing penalties on drivers who leave keys in unattended vehicles.[69] Lock design has been aimed at increasing the number of different key combinations in order to reduce the thefts due to "try-out" or "master" keys.

A more fundamental change in the ignition system and other automobile components is needed. Many possibilities exist. Spring ejection locks can prevent the driver from leaving the key in the ignition; sturdier housings can enclose the ignition terminals; heavier metal cable can surround the ignition wires; steering-wheel or transmission-locking devices can be used, as is done on several foreign cars. In 1960, the Federal Republic of Germany made the following a part of the Highway Code: "Passenger cars, station-wagons and motorcycles should be equipped with an adequate safety device against unauthorized use of vehicles. The locking of the doors and removal of the ignition key are not regarded as safety measures within the meaning of the preceding sentence." The "adequate safety device" includes steering column locks, gearbox locks, gear-lever locks, devices mechanically preventing starting of the engine, and spoke locks. These devices must also satisfy the requirements for traffic safety, e.g., an unintended blocking of the steering mechanism while the vehicle is in motion must be impossible.

Since the installation of such devices, the rate of auto thefts in West Germany has decreased from 1,244 thefts per 100,000 cars in 1961 to 829 thefts per 100,000 cars in 1964. The West German Federal Criminal Police feel that "the statistics definitely indicate that the additional protective devices have been effective in reducing motor vehicle thefts. They recognize that very probably a large percentage of this reduction has been in the category of what might be described as 'joyriding' thefts as distinguished from thefts committed by more skilled and determined thieves." [70]

This problem has been discussed by Task Force and Department of Justice representatives with the four major automobile manufacturers. The manufacturers have agreed to develop and install devices to increase the security of their products. These will include making the ignition system connector cable much more difficult to remove from the ignition lock, increasing the ignition key combinations, and locating the ignition system in less accessible places. These basic improvements will be made in the 1968 models. One manufacturer plans to install on its 1968 models a buzzer which will signal the driver when he opens the door that he has left his key in the ignition. Hopefully, other manufacturers will also address this problem.

Although the above steps will contribute to the reduction of auto thefts, the following additional improvements should be carefully considered:

> A steering column and/or transmission lock which immobilizes the car when the gear-shift lever is put into the proper position and the key removed. With this type of lock, starting an engine by shorting the ignition does not permit the car to be driven away.
>
> An ignition system which causes the driver to remove the key from the ignition. This can be done by a spring-loaded lock or key which pushes the key out; or by requiring the key to be not only turned, but also pulled out of the ignition in order to stop the engine; or by attaching a buzzer which goes off if the key is left in the ignition when the engine is turned off.

Although the automobile manufacturers are best able to integrate such devices into the design of their vehicles, it is desirable that some Federal agency work with them to establish minimum requirements on the actual implementation. This responsibility could well be assigned to the National Highway Safety Bureau as part of its program to establish safety standards for automobiles.

STREET LIGHTING

Improved street lighting is frequently advocated by police and highway departments as an important tool for combatting crime. Its proponents believe that adequate

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[57] In mathematical terms, a typical problem is one of estimating R with the function $R=f(T,P)$ where R is the probability of recidivism, T is a set of treatment attributes, and P is a set of personal attributes of the individual. The function f is generally assumed to be linear, and the statistical problem is one of estimating its coefficients from the available data, and then finding the treatment T that minimizes R for each individual with attributes P.

[58] Anderson, T. W., "Introduction to Multivariate Statistical Analysis," J. Willey & Sons, New York, 1958.

[59] Miller, Robert G., Statistical Prediction by Discriminant Analysis, Am. Meterological Society, vol. 4, No. 25, October 1962; Rettig, S., Multiple Discriminant Analysis: An Illustration, "Am. Sociological Review," 13, 398–402, 1964.

[60] Warner, Stanley L., Multivariate Regression of Dummy Variates under Normality Assumptions, "Journal of American Statistics Association," 58, 1054–63, 1963; Cox, D. R., Two Further Applications of a Model for Binary Regression, "Biometrics," 45, 562–5, 1958.

[61] "Los Angeles Police Statistical Digest," 1964, 1965.

[62] Study on Distance from Point of Theft to Point of Recovery done by the Chicago Police Department for July 15 to July 21, 1966.

[63] Berkeley, Calif., Police Annual Report, 1965.

[64] Uniform Crime Reports, 1965, p. 18.

[65] Uniform Crime Reports, 1965.

[66] Berkeley, Calif., Police Anual Report, 1965.

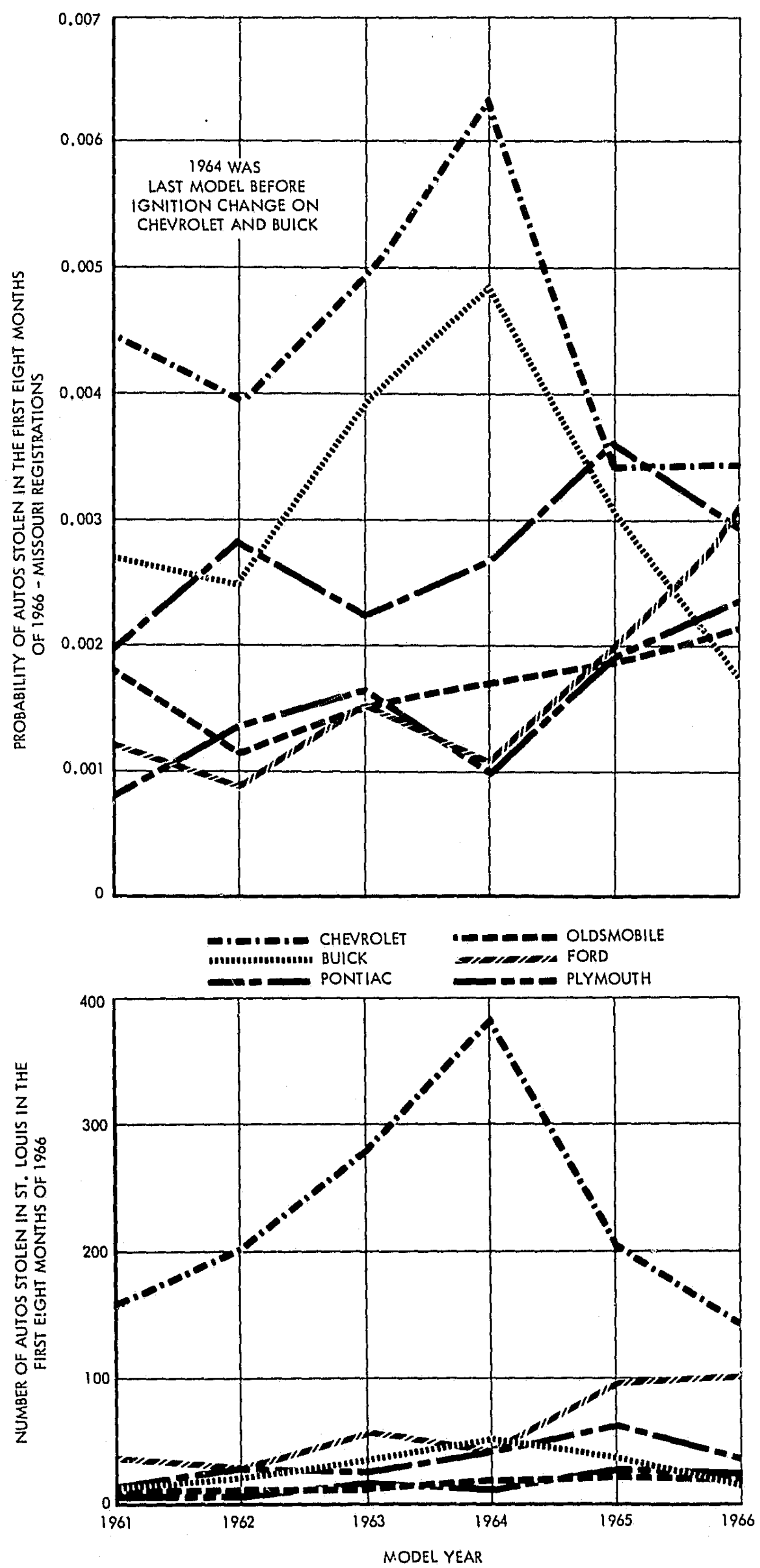
[67] Milwaukee, Wis., Second Quarter 1966, Statistics on Auto Theft, July 14, 1966.

[68] The *Houston* police chief reported that a 1965 educational campaign contributed to a 13-percent reduction in auto thefts during 1965. The first 10 months of 1966, however, showed a 49-percent increase in auto thefts in Houston over the same period of 1965. ("Action Report" of the National Automobile Theft Bureau; January–February 1967).

[69] It has been reported that in one country in South America police officers are instructed to deflate tires of vehicles in which keys are left, thereby ostensibly protecting the owner's vehicle from auto theft. Another possibility which is sometimes discussed is removing the keys to the nearest police station for safekeeping.

[70] Memorandum, American Embassy, Bonn, Germany, July 20, 1966.

FIGURE 16. AUTO THEFTS AS A FUNCTION OF MAKE AND MODEL YEAR



street lighting will (1) deter certain types of street crimes by increasing the risk of detection of the offender; and (2) enhance the probability of apprehending the offender. These assumptions are fortified by the general sense of security which is induced in the individual by the presence of adequate street lighting. Police and citizens alike frequently remark that they have no proof that improved street lighting reduces crime, but they do know that they feel safer. And if lighting encourages greater use of public streets and parks, this in itself may discourage criminals. Since much of crime occurs at night, there is considerable intuitive support for the feeling that street lighting will suppress crime incidence. According to data compiled by the Los Angeles Police Department during the year of 1965, there were 164,000 reported offenses and attempts. Of these, 49,000 were committed during the day, 75,000 at night, and 40,000 at unknown times. Likewise, certain crimes such as highway robbery, aggravated assault, purse snatching, and rape have a higher probability of being perpetrated at night.

Unfortunately, existing studies do not present definitive conclusions as to the effects of lighting on crime.

In 1956, the central business district of Flint, Mich., was relighted. Six-thousand-lumen incandescent lights were replaced with 20,000-lumen multiple flourescent bracket-type lights. A study over a 6-month period indicated that there was a 60 percent reduction in the number of felonies and misdemeanors, and 80 percent reduction of larcenies. However, there was, at the same time, an increase in police surveillance in the area. Since the experiment was not controlled, the effects of patrol and relighting are combined, so that any conclusions on the effects of street lighting must be considered only tentative.

In New York City, four police precincts designated as high crime areas were converted from incandescent lighting to mercury vapor lighting. The rate of nighttime crimes dropped by 49 percent after the installation of the lights. In 1964, after 80 percent of the city street lighting had been converted over a 4-year period at a cost of $58 million, the total felonies in the city increased by approximately 43 percent. It is impossible to determine what the felony rate would have been if the lights had not been installed.

In St. Louis, there seems to exist evidence of a favorable impact by street lighting on certain types of crime. A program of improved street lighting was first begun in 1964 in a principal business district in the downtown area. In a comparison of recorded criminal acts in 1963 with those of 1965, it was found that crimes against the person decreased by 40.8 percent, auto theft by 28.6 percent, and business burglaries by 12.8 percent. In another study involving a high crime district known as Central West End, an increase in crimes was recorded, but the rate of increase was not as high as in the surrounding areas. In addition, the overall increase of crime was lower than anticipated in these two areas.

The studies do not present definite conclusions as to the effects of lighting on crime. Methodologically, there are many problems which need to be overcome before definitive statements can be made. For example, very few experiments can be labeled as controlled. As noted in the Flint study, improved street lighting may be accompanied by other changes such as increased police surveillance. Likewise, subtle changes in the size and character of the population may accompany the lighting change and markedly affect the crime rate.

In addition to these problems, the task of conducting unbiased and controlled experiments is difficult and may involve considerable expense. One would want to discover which crimes were affected and under what conditions, i.e., what kinds of lighting are effective in what kinds of situations. This would require a statistical breakdown of crimes by block before and after relighting, not only in the relighted area, but in adjoining areas. It would require information as to the past, present, and projected crime rates and it would involve correlating these rates to the kind and intensity of the light. At present, these data are not available. The only results it is possible to reach now are:

> There is no conclusive evidence that improved lighting will have lasting or significant impact on crime rates, although there are strong intuitive reasons to believe it will be helpful.
>
> Improved street lighting may reduce some types of crimes in some areas, i.e., given a light and dark street to commit a crime, a criminal will probably choose the dark street.
>
> Improved street lighting accompanied by increased police patrol can reduce crime rates in an area.
>
> When new lighting programs are instituted, police departments should be encouraged to maintain records of crimes in the relighted and adjoining areas. With information on past, present and projected crime rates, it may be possible to assess better the impact of lighting on crime.

Analysis of Crime and the Overall Criminal Justice System

NEED FOR ANALYSIS OF THE OVERALL CRIMINAL JUSTICE SYSTEM

Previous chapters have examined some of the ways in which systems analysis can be used to help improve the operations of the police and court components of the criminal justice system. There are distinct limitations, however, in looking only at the parts. What is also needed is a means of relating the parts to each other. The criminal justice system must be viewed as an integrated whole, especially in formulating budgets and in developing programs at State and local levels.

Police, court, and corrections officials all share the objective of reducing crime. But each uses different, sometimes conflicting, methods and so focuses frequently on inconsistent subobjectives. The police role, for example, is focused on deterrence. Most modern correctional thinking, on the other hand, focuses on rehabilitation and argues that placing the offender back into society under a supervised community treatment program provides the best chance for his rehabilitation as a law-abiding citizen. But community treatment may involve some loss of deterrent effect, and the ready arrest of marginal offenders, intended to heighten deterrence, may by affixing a criminal label complicate rehabilitation. The latent conflicts between the parts may not be apparent from the viewpoint of either subsystem, but there is an obvious need to balance and rationalize them so as to achieve optimum overall effectiveness.

This process of balancing and rationalizing potentially inconsistent subobjectives is done at present, when it is done at all, on a largely subjective basis rather than through measured assessment of the consequences of various alternatives. The allocation of necessarily limited budgets and the choice of methods with which to handle various offenses and offenders could be done more accurately if such overall system assessment could be made.

Systems analysis provides one framework for attempting an objective assessment of the criminal justice system as a whole. The discussion in this chapter takes some preliminary steps in these directions, using a simulation model of the criminal justice system. The model was developed and computations performed with the limited available data, supplemented by hypothetical data, more to illustrate what might be done than to arrive at definitive conclusions. As such, the work raises some basic questions and provides a foundation upon which further research can be built. It also identifies data which must be collected to be able to evaluate alternative actions in the total system context.

One of several possible examples can illustrate how little of the basic data is now available. Although it is fairly well documented that there are over 6 million arrests made each year in the United States for nontraffic offenses, it has not been known what percentage of the population ever gets arrested. The incompleteness of most arrest records makes it difficult to estimate the proportion of arrests in any year that are of persons never before arrested, a figure necessary for determining what percentage of the population ever gets arrested. A mathematical analysis presented in appendix J used the lowest estimate—one new offender in eight arrests—on the basis of which it was calculated that if present trends continue at least 40 percent of the male children living in the United States today will be arrested for a nontraffic offense sometime in their lives. For boys living in cities, the figure is in the order of 60 percent; for Negro boys living in cities, it is about 90 percent. These projections are based on current arrest rates, which have been increasing in recent years, so in some respects they might even be conservative. On the other hand, the inherent incompleteness in arrest records leaves open the possibility that even the one-eighth estimate at the first-arrest rate may be high. Of course, changes in arrest practices, such as widespread adoption of the Commission's recommendation not to treat drunkenness as a criminal offense, could reverse the trend.

The fact that these projections are so surprising to most observers illustrates how little is known in fact about basic questions in the criminal area and how important it is to try to find more answers. For if sustained by additional data, these estimates must raise many basic questions about the operation of the criminal justice system and about the nature of police intervention. They would refute the common notion that most people never encounter the criminal justice system and only a small class of "criminals" do.[71] Although these statistics, and many like them, are vital to understanding how the criminal justice system operates and to raising critical questions, there are now no estimates, however tentative, of many such numbers.

Even more important for policy guidance is the need for information on the likely consequences of actions that change the system. One way to collect data about such

[71] This could be erroneously inferred from the fact that a high proportion (roughly 75–90 percent) of those arrested have a prior arrest record.

relationships would be to make changes in the operations and observe the effects directly. Wherever practical, this kind of controlled experimentation is clearly to be preferred. But it is often impractical and even undesirable. Not only are the costs often prohibitive, but normal operations are frequently too sensitive to be disrupted. Instead, it may be possible to formulate a mathematical description or "model" of the system which, with data collected from the current system, could be used to explore the relationships among the various parts. The construction and manipulation of such mathematical models to find out how better to organize and operate the real-life systems they represent is a basic part of systems analysis.

Such models of the criminal justice system are desirable for several reasons:

> They develop an explicit description of the criminal justice system and its operating modes so that the system's underlying assumptions are revealed.
>
> They provide a vehicle for simulated experimentation in those instances where "live" experimentation is impractical or undesirable.
>
> They identify what data must be obtained if essential calculations are to be made of the consequences of proposed changes.

These advantages must be considered in light of a sober appreciation of what cannot be done by constructing and using models. The cause-and-effect relationships in the real world of criminal justice are so complex and so intricately interwoven that any mathematical description of them is bound to be a gross simplification. At the present time, even the most basic relationships are poorly understood, and the available data contribute little to further understanding. Moreover, in so dynamic a system the causal relationships themselves change constantly. They will change further as increased understanding changes people's behavior. Clearly, a system of this magnitude and complexity cannot be studied in detail even descriptively, much less analytically, in a few months by a few people.

However, sufficient benefits have accrued from similar analyses conducted on equally complex systems, such as air traffic systems or national economies, to warrant probes in this direction for the criminal justice system. The State of California has already supported a pioneering study of this sort by the Space-General Corp. The Task Force further developed these approaches in order to lay a foundation on which additional analytical development of the criminal justice system could be based and also to identify some of the primary data needs.

One benefit of this approach, if it is developed, is the ability to conduct cost-effectiveness analyses. These analyses, applied with particular success in the Department of Defense, provide a means for determining which of several alternative courses of action would yield maximum crime-control effectiveness for a given cost, or minimum cost for a given effectiveness.

Such analysis can be brought to bear only on those aspects of crime and criminal justice that are amenable to quantification. These measurable values must always be considered in relation to what are frequently more important, often unquantifiable values, in making any decisions about modification of police, court, or corrections operations. The cost-effectiveness approach does not force a quantification of unmeasurable human values. Rather, it sets out those implications that are quantifiable, and thereby permits a sharper focus on the critical value questions of social policy by the legislator and the administrator.

MEASURING THE EFFECTIVENESS OF THE CRIMINAL JUSTICE SYSTEM

Systems analysis begins with an examination of the objectives of the system of interest. These objectives are then translated as far as possible into quantitative measures of effectiveness of the system. Various alternative means of improving the system can be compared numerically with a mathematical model which calculates the measures of effectiveness associated with each alternative. At the current state of development, with only very poor data and gross uncertainty about the consequences of any actions taken, any attempt to accomplish this for the criminal justice system must be regarded as preliminary.

The criminal justice system is generally regarded as having the basic objective of reducing crime. However, one must also consider its larger objective of minimizing a total net social disutility associated with crime as well as crime control. Both of these components are complex and difficult to measure completely. The social costs associated with crime come from both the long- and short-term physical damage, psychological harm, and property losses to victims as a result of crimes committed. Crime also creates serious indirect effects. It can induce a feeling of insecurity that is only partially reflected in business losses and economic disruption due to anxiety about venturing into high crime rate areas.

Balanced against these costs associated with crime must be the consequences of actions taken to reduce them. Money spent on developing, maintaining, and operating criminal justice agencies is only one part of this. It also includes the indirect costs of the crime control system, such as welfare payments to prisoners' families, lost income of offenders who are denied good jobs, legal fees, and lost wages of witnesses. In addition, there are penalties associated with suspects erroneously arrested or sentenced, the imposition on personal liberty resulting from police surveillance, and the limitations on privacy in maintaining criminal records.

This balance between reducing the costs of crime and of crime control is reflected in the fact that the criminal justice system exercises only a limited amount of crime control (e.g., policemen are not posted on every street corner) and under strict constraints (e.g., limitations on search). Thus, there is an "optimum" level of crime control effort reflecting this balance of costs, and any effort at improving crime control must weigh the additional social costs imposed thereby. This optimum level reflects how society weighs the factors in the balance at any particular time.

Systems analysis, being limited to working with what can be measured, cannot deal with all these factors. Hence, the major emphasis in this chapter is on the direct operating costs incurred by the system, which are relatively easy to measure, and the amount of crime, which is considerably more complex but still approachable quantitatively.

MEANS OF CRIME CONTROL BY THE CRIMINAL JUSTICE SYSTEM

The criminal justice system works to reduce crime in three basic ways:

- ☐ *Deterrence*—posing a threat of apprehension and consequent penalties;
- ☐ *Incapacitation*—removing individuals from places where they might commit further crimes or subjecting them to supervision that makes it difficult for them to do so;
- ☐ *Rehabilitation*—treatment by correctional agencies.

Each of these methods is obviously extremely complex and our knowledge about them is very inadequate at present. Rehabilitation, for instance, appears in many cases to have been relatively ineffectual; limited data suggest that roughly one person in three released from prison will return and that over three-quarters of those once arrested will be subsequently arrested. Rehabilitation is an extremely complex task in which methods that succeed in one instance fail in another. Furthermore, gains in treatment may be easily offset by factors entirely unrelated to the criminal justice system, such as the inability of a released offender to get a job or the acquaintances he makes when he returns to the community.

Incarceration has inherent limitations as a method for the general control of crime. Of all the Index crimes reported to the police, only about 25 percent are cleared by arrest. About 10–20 percent of the individuals arrested are sentenced to jail or prison. The jail terms are less than a year, and the average prison time is about one and a half years. So only a small percentage of the total possible crimes that could be committed on any given day are avoided by imprisonment.[72] Probation and parole supervision may also serve to some extent to incapacitate, but how much they do is clearly hard to measure and no data on their restraining effects exist at present.

The effects of deterrence are much more subtle and difficult to measure even than those of rehabilitative programs. One basic question is the degree to which deterrence is uniform over the population, or whether the population can be divided into identifiable classes with distinctly different responses to deterrence. In particular there is the question of whether people with criminal histories—those who were not deterred at least once in the past—are less deterred than those without such records. Another question is the extent to which the actions of the criminal justice system deters people from committing crime as compared to the extent to which they are deterred by things like general public opinion, the reactions of family and friends, religion and morality, and the fear of losing a job. Within the criminal justice system, it is not known in what measure deterrence is effected by the fear of being caught by the police, by the threat of a prison sentence, or by the stigma of a record. As difficult as these questions are they lie at the heart of the operation of the criminal justice system, and so must be addressed in a major research program involving analysis and experimentation. Until we begin, however, decisions will be based on intuition rather than on observed fact.

MEASURING CRIME

There are different ways of measuring the amount of crime, and they do not necessarily imply the same thing. Two basic directions can be taken. The first, determining the degree of public safety, is to measure the probability of a person in a certain category being a victim of a crime. The second, determining the extent of criminality within the society, is to measure the probability that an individual with specified characteristics will commit a crime.[73]

From the viewpoint of evaluating public safety, the absolute number of crimes fails to reflect accurately the victimization probability. If crimes increase in proportion to population increase, then there is no change in the gross victimization probability. Crime rate, the number of crimes per 100,000 population, measures victimization more accurately.

This same crime rate is often used as a measure of criminality. Different population groups differ in their propensity to commit crimes,[74] however. Crime rates are influenced by the age distribution of the population, by the extent of urbanization of the population, by the ethnic mix in different geographical regions, and many other demographic factors. Thus, crime rates could increase as a result of demographic changes (e.g., a decrease in the median age of the population) even without an increase in the criminality of any population subgroup.

Crime rates always measure the number of certain crimes divided by a measure of exposure. It is important that the exposure be defined in relation to the purpose for which the crime rate is to be used. For example, if we want to know how safe our 1964 Chevrolet is from theft, we are interested in the number of autos, or, even better, the number of 1964 Chevrolets stolen in our area each year per 100 autos. If we want to know how safe we are from robbery in a certain area, we are interested in the number of robberies in the area per year per 100 people in that area. If we want to know the chance of our son committing a crime this year, we are interested in the percentage of boys his age in the area who commit crimes in a year. The more finely the data can be divided, the more directly relevant it is to the question of interest. Most interpretations of crime statistics fail

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[72] This means, neglecting the deterrent effects of imprisonment and the rehabilitative effects of associated correctional programs, and concentrating only on the removal effects of incarceration, that the amount of crime would increase by only a small percentage if there were no incarceration at all.

[73] These problems have been treated by the Assessment Task Force and are discussed in detail in their report.

[74] The characteristics of those who commit crimes cannot be learned directly. The necessary approximation involves using the characteristics of arrestees. This introduces the possible bias that some types of criminals (e.g., the younger ones, the poorer ones, and the less intelligent ones) may be more likely to be arrested than others.

to identify the exposure rate associated with the intended interpretation.

Pervading all measures of crime is the inability to distinguish between changes in the amount of crime committed and the amount of crime reported. This difficulty is aggravated when the two are correlated, as they are in public reports of crime to the police. As the police became more effective in solving crimes and in recovering property, the reported rate might increase even though the actual rate might decline. This difficulty can be minimized by using several different approaches (e.g., victim surveys as well as police reports) to estimating the volume of crime. Even when there is a true change in crimes committed, it is extremely difficult to separate the results of actions by the criminal justice system from independent social changes, such as reduction in discrimination, economic improvement, or modifications in school systems.

Gross rates of victimization or commission of crimes, even if they could be obtained accurately and completely, would still fail to present an adequate picture of the magnitude of the crime problem. Each type of crime has a different degree of seriousness. The distribution of crimes among the different types is an important fact. In the District of Columbia, for example, the number of part I [75] crimes rose by 2,712 (8 percent) from 32,053 to 34,765 between 1965 and 1966. However, petty larceny, the least serious of the part I offenses, rose 2,729. There was a slight net decrease in both the number and the rate of the other, more serious, part I offenses.[76] Thus, it is difficult to say whether the crime problems grew more or less serious in Washington without measuring the relative seriousness of the different offenses.

FBI estimates of the index of crime are derived from an unweighted sum of the reported Index crimes. This Index is dominated by the far more prevalent crimes against property and is relatively insensitive to changes in the serious crimes against the person. Thus, murders could increase by 1,000 percent, but if auto theft fell by 10 percent, the Index would decline.

All crimes are not equally undesirable. Most people would be willing to tolerate a considerable amount of private gambling, or perhaps even shoplifting, if they could know that doing so would reduce the amount of street robberies. The trade-offs among different types of crime is an important consideration in allocating enforcement resources. Decisions, for example, on transferring detectives from the vice squad to the robbery squad should take into account the relative amounts of crime disutility they could reduce on each squad.

Crime derives its seriousness from many different effects. It is extremely difficult to assess these in order to determine their relative importance. One way of resolving these difficult issues is to measure public attitudes toward being a victim of different crimes, using a representative sample of individuals and applying scaling techniques. Some preliminary results have been obtained by Sellin & Wolfgang.[77] They asked a sample of people to weigh the seriousness of various crimes.[78] The concepts of utility theory can then be applied [79] to these values, resulting in estimated disutilities of each part I crime roughly as shown in table 10. This ranking of seriousness differs somewhat from the UCR ranking of seriousness, which is also shown in table 10.

Table 10.—Disutilities of Part I Crimes

Type of crime ranked by UCR seriousness	Estimated average disutility
1. Criminal homicide	[1] 400,000,000
2. Forcible rape	[1] 10,000,000
3. Robbery	10,000
4. Aggravated assault	20,000
5. Burglary	200
6. Larceny ($50 and over)	100
7. Auto theft	900
8. Larceny (under $50)	90

[1] The disutilities for criminal homicide and forcible rape are very crude estimates based on an extrapolation extending far beyond the region for which data were available concerning the functional form of the relationship between scale value and utility.

Thus, if a "rational person" strives to minimize his average disutility, then these numbers suggest that he is equally concerned about 1/200 probability of a burglary and 1/20,000 probability of an aggravated assault.[80]

These approaches, combined with those of Sellin and Wolfgang, could be used to develop an index of crime which more accurately reflects the total seriousness of crime than merely adding the offenses without attaching any weights to them.

In assessing the performance of the criminal justice system, the incidence of crimes must be balanced against the costs of crime control, including both the dollar costs, direct and indirect, and the social costs. One instrument for relating these cost and effectiveness measures is in a model of the criminal justice system.

A MODEL OF THE CRIMINAL JUSTICE SYSTEM

FORM OF A MODEL

The first step in developing a model of a generalized criminal justice system [81] is to describe in detail the events that occur as offenders are processed through the system. One such description, from the Commission's report, is illustrated in the next figure. Even this description is simplified, and differs from the real system in any particular jurisdiction. Transforming this description into a model involves the following steps:

(1) Aggregate a number of related processing stages consistent with the form of the available data. For example, the booking and initial appearance stages might be combined into a single one.

(2) Describe the probability that an arrested person is routed along the alternative paths out of each branching point in the diagram. This would include the proportion of individuals following each route as a function of the type of crime, characteristics of the individual such as age and prior criminal record, and characteristics of the processing stage.

(3) Attribute to each individual the costs of processing him at each stage.

(4) Determine the resources required to process the flow of individuals through each stage.

(5) For each possible route out of the system, describe the probability that an individual will again commit a crime as a function of his prior crime, his personal characteristics such as age, and the treatment provided.

(6) Translate these descriptions into computer language so that numerical results can be calculated.

(7) Collect data to estimate each of the model parameters in the above descriptions.

(8) Change the variables characterizing the system, and calculate the consequences of these changes on costs and on crimes.

A simplified version of the model which was developed by the Task Force following this process is shown in figure 17. It can be used to calculate what happens to arrested offenders as they flow through court and corrections subsystems. The analysis was restricted to the seven Index crimes and to offenders processed for committing them through either felony court or juvenile court.

Each of the seven Index crimes was treated separately. The results for all the Index crimes were then totaled to obtain the costs incurred at each stage, and the number of people traveling each route shown in the figure. In order to make these calculations, data were gathered to describe operating procedures and costs. Often best estimates, approximations, or extrapolations to the whole country of data characteristic of specific jurisdictions had to suffice. Because of the gaps in the data, the numerical results must be viewed as tentative, but they are presented to illustrate the potential uses of the analysis and to give impetus to the collection of proper data for use in more definitive studies.

Data on crimes and arrests were based on data from the FBI "Uniform Crime Reports." [82] The probabilities describing the routing of offenders through each branching point were based on data from a sampling of State court reports for court and probation processing and on California [83] practices for correctional and juvenile processing.

As in all accounting, allocation of costs to crimes and to offenders often requires arbitrary judgments, especially in distributing fixed costs. Police costs were developed from information provided by the International Association of Chiefs of Police. They estimate that it would be reasonable to allocate 25 percent of patrol costs and 100 percent of detective costs to Index crimes.

Court costs were based on estimates in the District of Columbia of the time spent by the prosecutor and his staff, the judge and his staff, and witnesses and jurors on each type of crime as a function of the type of trial. Corrections costs were based on estimates by the Corrections Task Force of the cost per offender-year in prison and jail.

The costs for processing juveniles through courts and corrections are based on California costs and are underestimated since the only available cost data did not distinguish between the costs of processing juvenile Index crime offenders and other minor violaters.

The cost calculations use an estimate of the processing time per case or offender. Hence, resource requirements can be easily calculated with data on the processing rate of each relevant resource: judges, prosecutors, probation officers, parole officers, prison guards, prison cells, etc.

The model can also be used to calculate the system's effectiveness in reducing crime by persons after they have been processed. At any stage in processing, offenders can be released, dismissed, acquitted, discharged, or otherwise returned to the general population. When this happens, there is a chance of rearrest and reprocessing through the criminal justice system. This feedback feature permits the tracing of lifetime criminal career patterns—number of arrests, crimes arrested for, mean length of criminal careers—of individuals as they are recycled through the criminal justice system.

Calculating these criminal career patterns requires estimates of the probability of recidivism or recommission of crime for each type of offender leaving each processing stage. In the model, recidivism is related to offender variables, such as age and previous criminal history. It should also be related to variables characterizing the treatment (a person released by the police without being charged may have a different propensity to commit a new crime than one who is discharged from prison after serving a term) but such data are not now generally available.

There are many ways to measure recidivism. It would be desirable to know the probability of reversion to crime for each type of offender as a function of the point of exit from the system. Unfortunately, direct data on reversion to crime would be impossible to develop because information on who committed an unsolved crime is impossible to obtain. Because of this difficulty, other measures of recidivism must be used. Some researchers, particularly those focusing on the corrections process, describe recidivism in terms of the probability that an offender released from corrections will be returned to corrections. This provides an underestimate of recidivism by those individuals because of the many opportunities for someone who committed a crime to drop out of the system, as illustrated by the funneling effect of figure 18. For example, studies have shown that approximately one-third of the offenders released from prison will return. Typically, in the United States as a whole, 20 percent of

[75] Part I crimes are the Index crimes plus negligent manslaughter and larceny under $50.

[76] Report of the President's Commission on Crime in the District of Columbia, 1966, p. 24.

[77] The Measurement of Delinquency, Sellin & Wolfgang, J. Wiley & Sons, 1964.

[78] The crimes were defined so as to result in the amount of injury, property lost, property unrecovered, property damages, etc., typical of such crimes actually committed by juveniles.

[79] The Sellin-Wolfgang indexes for larceny crimes were translated into a utility scale based on the monetary loss in the larceny. (For a definition of the utility scale and a discussion of its use in decisionmaking, see the classic work of John Von Neuman and Oscar Morgenstern, Theory of Games and Economic Behavior, Princeton UP, 1948.) The other crimes were then interpolated onto this scale based on their Sellin-Wolfgang scale values.

[80] Of course, there are infinitely many possible scales of weights which are monotonic in seriousness. Since they are all nonotonically related, maximizing "value" as measured on any one of the scales maximizes it on all of them. The unique feature of utilities as distinguished from other measures of "value," is that, roughly speaking, the marginal utility of an outcome is inversely proportional to the probability risk of its occurrence one is willing to take. This makes utilities particularly useful in analyses of decisions on actions directed at affecting the probabilities.

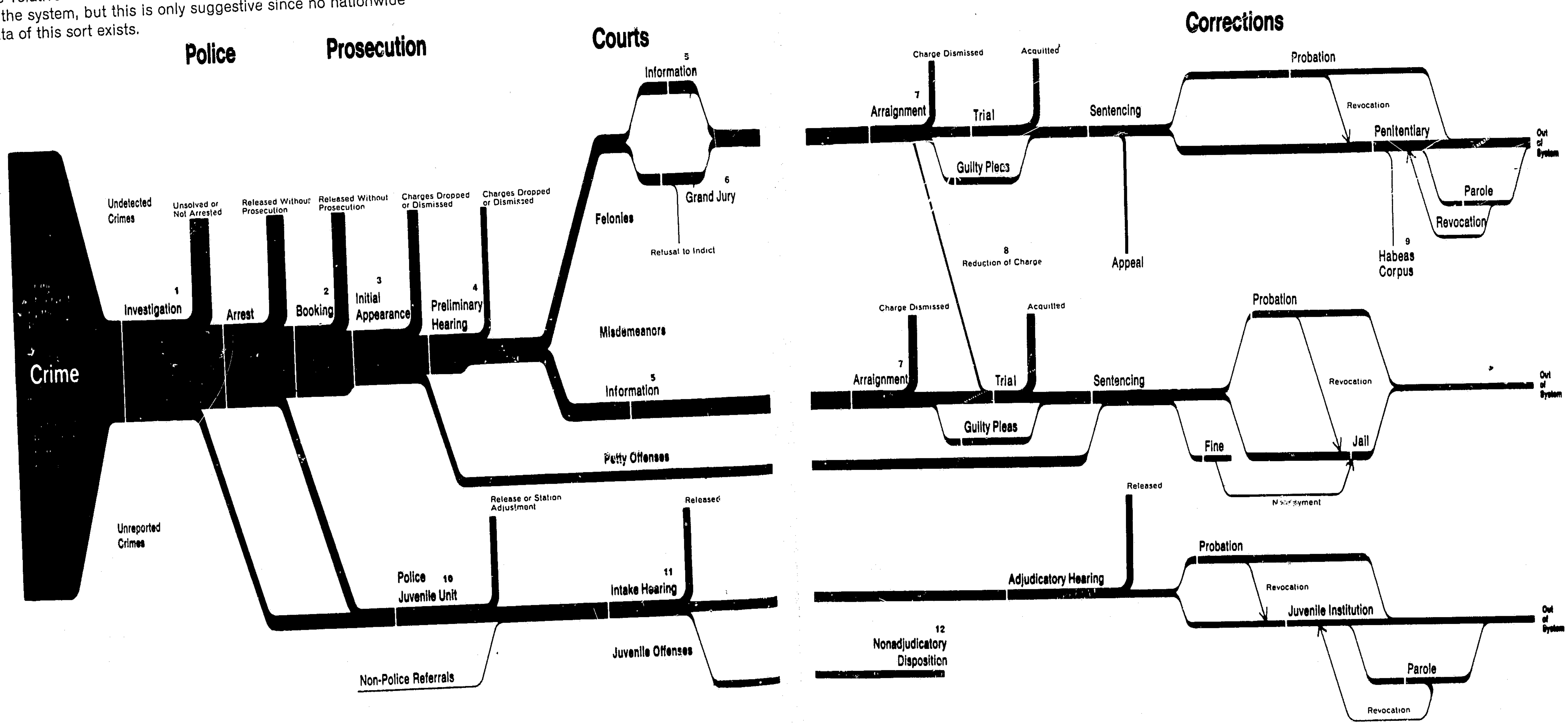
[81] The technical details are in "A Model of the Criminal Justice System," not in preparation. The report will be available from the Clearinghouse for Federal Scientific and Technical Information of the National Bureau of Standards.

[82] Federal Bureau of Investigation, U.S. Department of Justice, "Uniform Crime Reports for the United States," 1965, Washington, D.C.

[83] The reports from California provided the best published data on details of processing in the criminal justice system. The reports include: Bureau of Criminal Statistics, Division of Criminal Law and Enforcement, Department of Justice, State of California, "Crime in California, 1964." Administrative Statistics Section, Research Division, Department of Corrections State of California, "California Prisoners 1961, 1962, 1963," Sacramento, Calif. Bureau of Criminal Statistics, Division of Criminal Law and Enforcement, Department of Justice, State of California, "Delinquency and Probation in California, 1964."

A general view of The Criminal Justice System

This chart seeks to present a simple yet comprehensive view of the movement of cases through the criminal justice system. Procedures in individual jurisdictions may vary from the pattern shown here. The differing weights of line indicate the relative volumes of cases disposed of at various points in the system, but this is only suggestive since no nationwide data of this sort exists.



1 May continue until trial.

2 Administrative record of arrest. First step at which temporary release on bail may be available.

3 Before magistrate, commissioner, or justice of peace. Formal notice of charge, advice of rights. Bail set. Summary trials for petty offenses usually conducted here without further processing.

4 Preliminary testing of evidence against defendant. Charge may be reduced. No separate preliminary hearing for misdemeanors in some systems.

5 Charge filed by prosecutor on basis of information submitted by police or citizens. Alternative to grand jury indictment; often used in felonies, almost always in misdemeanors.

6 Reviews whether Government evidence sufficient to justify trial. Some States have no grand jury system; others seldom use it.

7 Appearance for plea; defendant elects trial by judge or jury (if available); counsel for indigent usually appointed here in felonies. Often not at all in other cases.

8 Charge may be reduced at any time prior to trial in return for plea of guilty or for other reasons.

9 Challenge on constitutional grounds to legality of detention. May be sought at any point in process.

10 Police often hold informal hearings, dismiss or adjust many cases without further processing.

11 Probation officer decides desirability of further court action.

12 Welfare agency, social services, counselling, medical care, etc., for cases where adjudicatory handling not needed.

individuals arrested for Index crimes are sentenced and only about 30 percent of these are sentenced to prison.

In the model, recidivism was measured at the point of rearrest. This brings into the sample a number of people arrested for crimes they did not commit, but reduces the error in ignoring people freed for legal or technical reasons even though they did commit the crime.

In this model, the probability that a person is rearrested was made to depend on his age, his previous crime, and on his exit point from the criminal justice system.[84] These probabilities of rearrest were defined for each type of Index crime as decreasing constantly with age.[85] The decrease is more rapid for some types of crime than for others.

The distributions of time lags between arrests were based on data from the FBI criminal careers study and on data from several jurisdictions. These data indicated that rearrest, if it happens, occurs within 5 years after release in about 99 percent of the cases and within 2 years in over 60 percent of the cases.

Another factor that must be included in a model to describe recidivism is the type of crime which a recidivist tends to commit. An individual's subsequent crimes are related to his previous crimes. The estimated array of these conditional probabilities for each of the seven Index crimes is shown in table 11. The table displays the chance of switching from each crime type to each other when rearrest occurs.

USES OF THE MODEL

Criminal Justice System Direct Operating Costs for Index Crimes

The direct costs of processing offenders at each stage were calculated for each Index crime on the basis of processing time and unit time costs. In figure 19, the system costs for each kind of Index crime are distributed among the major cost components. Corrections costs account for a large portion of the total cost in murder and nonnegligent manslaughter (81 percent), forcible rape (42 percent), and robbery (42 percent). In all these crimes, police clearance rates tend to be high. For the property crimes, which have lower clearance rates, police costs are a much larger proportion, about 70 percent of the total costs. For all the Index crimes, the court costs are a very small portion of the total: 8 percent for murder, 4 to 5 percent for the other personal crimes, and 1 percent for the property crimes. Figure 20 shows how these costs are attributable to each of the 1965 Index crimes in the United States in 1965. It can be seen that the property crimes of burglary, larceny of $50 and over, and auto theft, which account for 87 percent of the Index crimes, also account for the bulk (81 percent) of the system costs for Index crimes. The figure also shows how these system costs for Index crimes are distributed among the major system components. Police costs are the largest (67 percent), followed by correctional programs (including probation) which account for 20 percent.

In table 12 the system costs are presented as the cost per individual crime. Each reported Index crime costs the criminal justice system directly about $750. The cost per offender arrested, however, is about $3,000 since there are only about one-fourth as many arrests as Index crimes reported.

Another costing approach would omit the large amounts of police costs charged to the offenders, and charge them instead as fixed costs of the system. If offenders are not charged with any of the costs of police patrol, then the cost per offender arrested is reduced to about $1,000.

Criminal Careers

The criminal justice system pays a price for permitting a person to enter a life of crime. The cost is measured by the "criminal-career cost," or the total cost to the

FIGURE 18. FUNNELING EFFECT FROM REPORTED CRIMES THROUGH PRISON SENTENCE

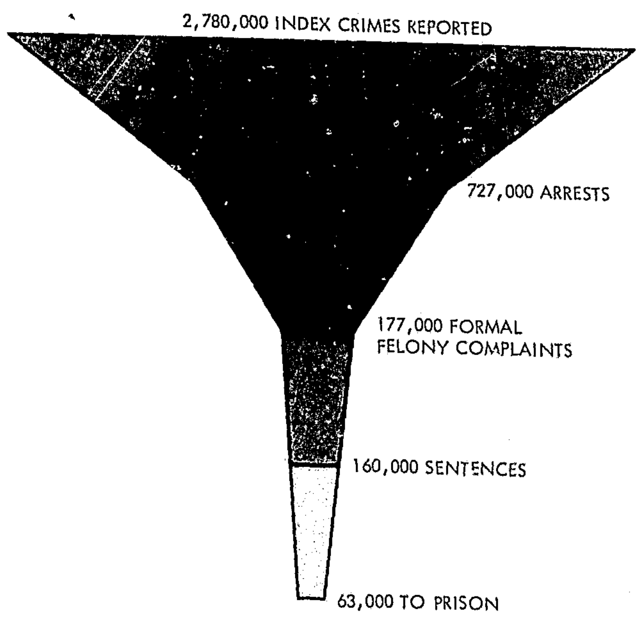
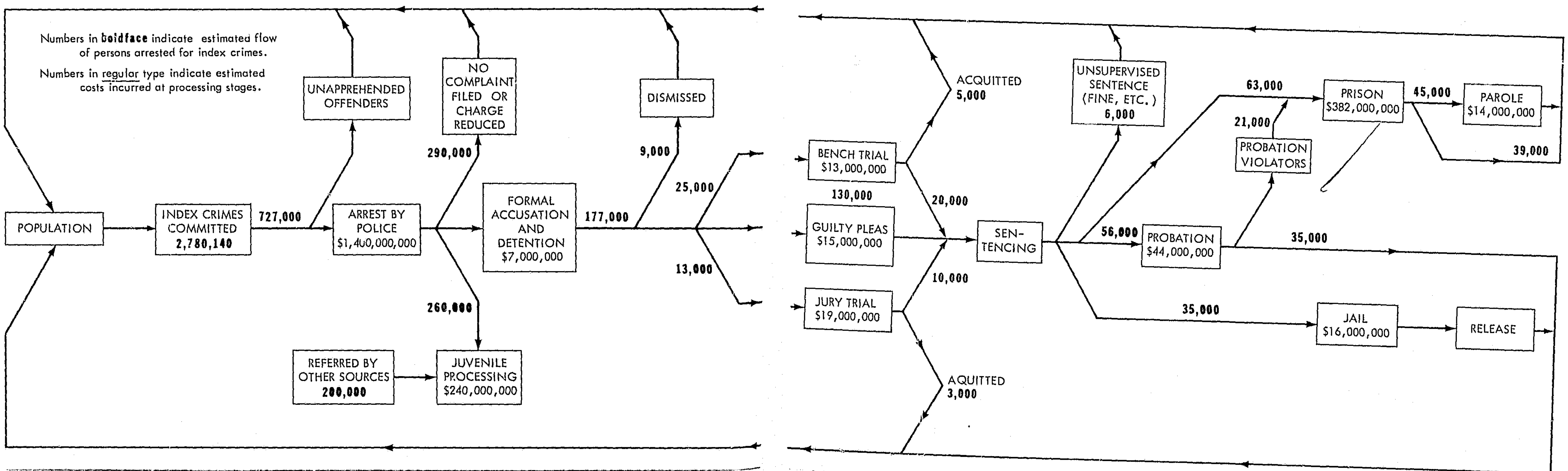


FIGURE 17. CRIMINAL JUSTICE SYSTEM MODEL WITH ESTIMATES OF FLOW OF OFFENDERS AND DIRECT OPERATING COSTS FOR INDEX CRIMES IN THE UNITED STATES IN 1965

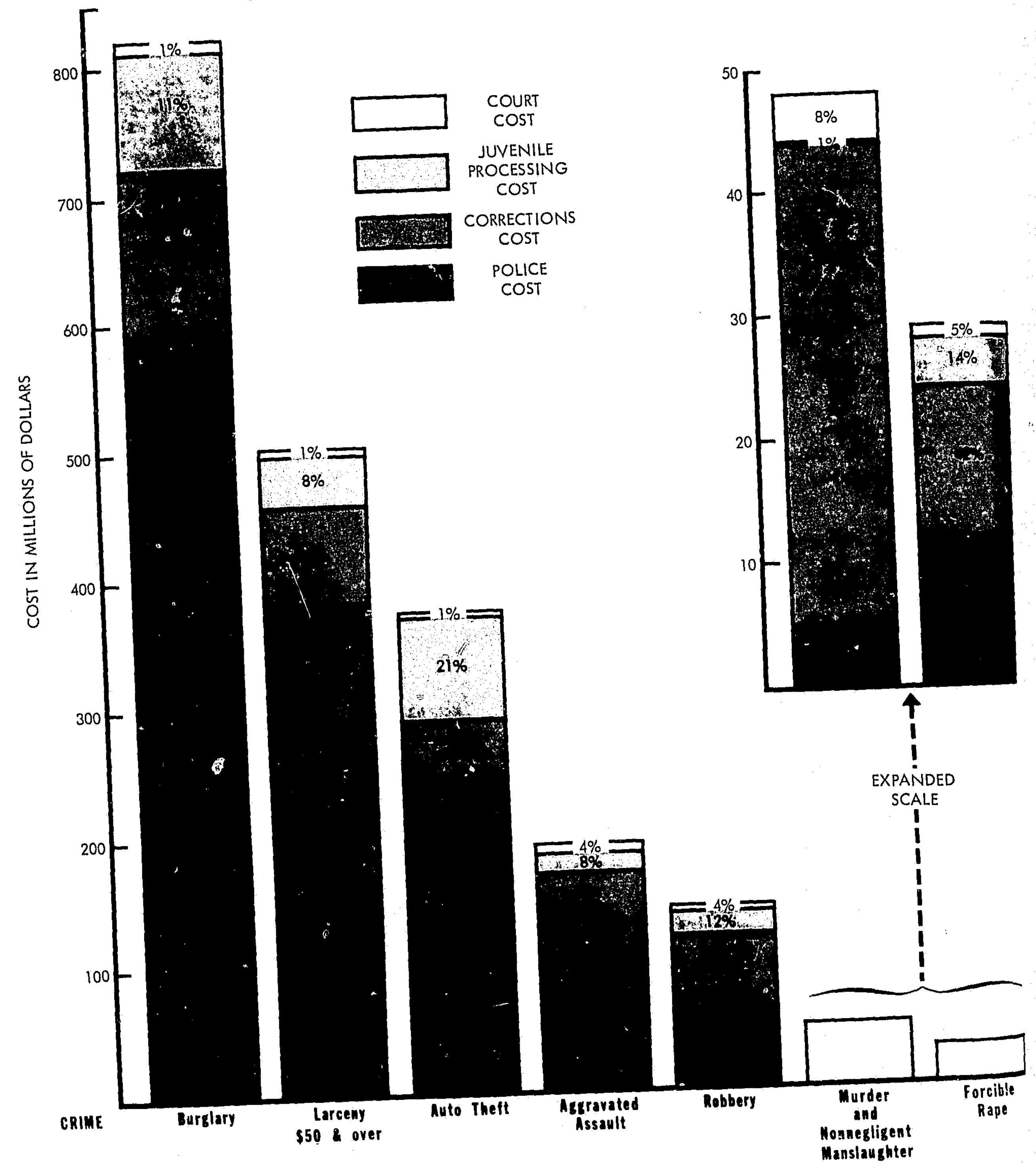


[84] Data from Glaser (The Effectiveness of a Prison and Parole System; Bobbs Merrill: 1964) was used for the rearrest probabilities for those leaving corrections. The data for the other rearrest probabilities used in the model to derive criminal career patterns were estimated so that the calculations would yield careers which approximated those in data collected by the Federal Bureau of Investigation and also give the closest approximation to arrest-age distributions given in the 1965 "Uniform Crime Report."

[85] For juveniles processed as such, the probabilities were assumed constant with age until they were processed as adults at age 18.

FIGURE 19. ESTIMATED CRIMINAL JUSTICE SYSTEM DIRECT OPERATING COSTS FOR U.S. INDEX CRIMES, 1965

Total Index Crimes - 2,780,000 Total Costs - $2,097,000,000



	Burglary	Larceny $50 & over	Auto Theft	Aggravated Assault	Robbery	Murder and Nonnegligent Manslaughter	Forcible Rape
Number of	1,173,200	762,400	486,000	206,700	118,920	9,850	22,470
Percent	39	24	18	9	7	2	1
Dollars (millions)	820	500	370	190	140	48	29

FIGURE 20. ESTIMATED DISTRIBUTION OF CRIMINAL JUSTICE SYSTEM DIRECT OPERATING COSTS AMONG MAJOR SUBSYSTEMS AND TYPES OF INDEX CRIMES, 1965

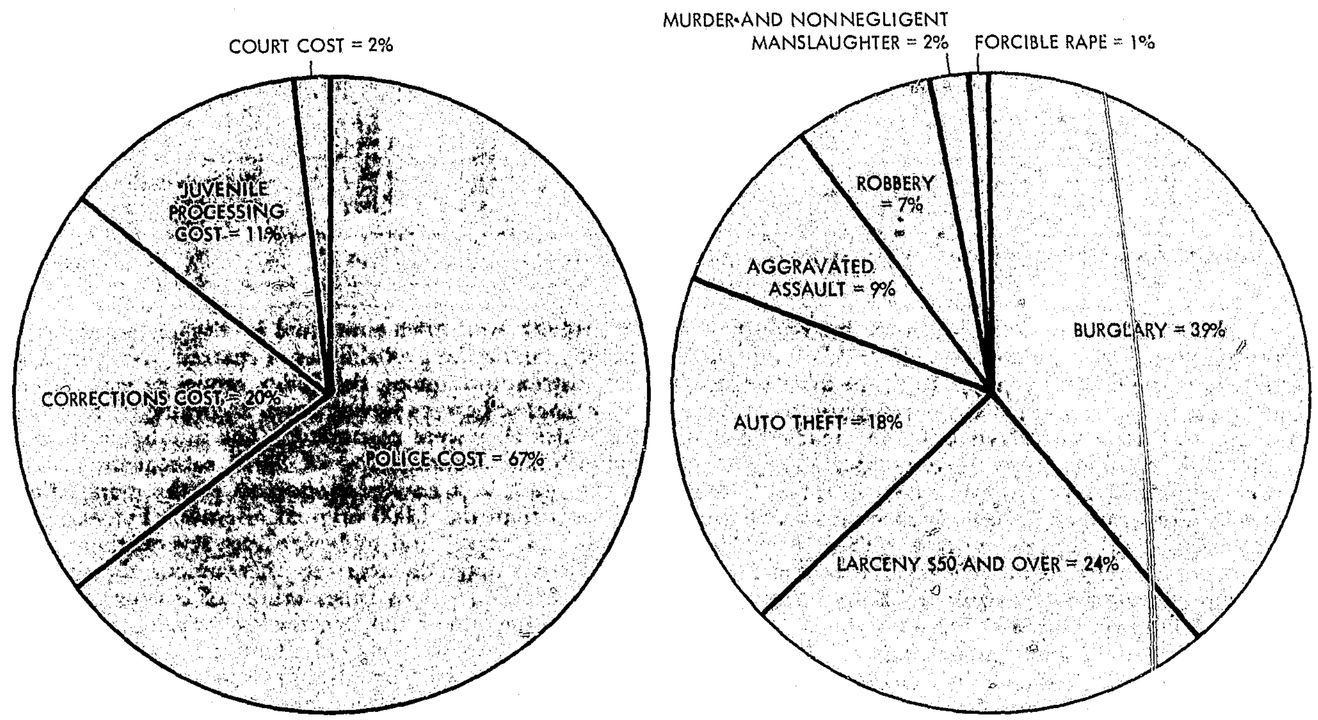


Table 11.—Rearrest Crime-Switch Matrix [1]

Last Index arrest for	If arrested again for an Index crime, the probability it will be for—						
	Murder and nonnegligent manslaughter	Forcible rape	Robbery	Aggravated assault	Burglary	Larceny ($50 and over)	Auto theft
Murder and nonnegligent manslaughter [2]	0.025	0.025	0.150	0.400	0.200	0.100	0.100
Forcible rape [2]	.020	.150	.110	.260	.200	.140	.120
Robbery	.015	.010	.350	.060	.350	.115	.100
Aggravated assault [2]	.025	.040	.150	.300	.085	.200	.200
Burglary	.010	.020	.135	.063	.459	.282	.031
Larceny ($50 and over)	.010	.020	.140	.025	.400	.275	.130
Auto theft	.010	.027	.045	.028	.390	.222	.278

[1] Based on data from Crime Revisited: Minnesota Board of Corrections; 1965 "Uniform Crime Reports," pp. 29–31; and Federal Bureau of Prisons, statistical tables, fiscal year 1965.

[2] Best estimates based on inadequate data.

Table 12.—Total 1965 U.S. Criminal Justice System Costs for Index Crimes [1]

Crime type	Total system costs (millions of dollars)	Number of crimes	System costs per crime (dollars)	Number of arrests	System costs per arrest (dollars)	Career costs [2] (dollars)
Willful homicide	48	9,850	4,900	9,400	5,100	12,600
Forcible rape	29	22,470	1,300	14,300	2,000	9,600
Robbery	140	118,920	1,200	54,300	2,600	13,500
Aggravated assault	190	206,700	920	108,000	1,800	9,400
Burglary	820	1,173,200	700	266,000	3,100	14,000
Larceny of $50 and over	500	762,400	660	144,000	3,500	11,900
Auto theft	370	486,600	760	131,000	2,800	11,000
All index crimes	2,097	2,780,140	750	727,000	2,900	[3] 12,200

[1] 100 percent of detective force costs and 25 percent of patrol force costs and court and corrections costs were allocated to Index crimes.

[2] Based on Index crimes with the 1st Index crime arrest occurring at age 16 for the indicated crime.

[3] Based on distribution of 1st arrests matched to distribution of arrests of individuals under 18 given in the 1965 "Uniform Crime Reports."

Table 13.—Criminal Career Patterns for Index Crimes [1]

1,000 initial arrests at age 16 for—	Number of lifetime rearrests for—							Total lifetime rearrests
	Murder and nonnegligent manslaughter	Forcible rape	Robbery	Aggravated assault	Burglary	Larceny ($50 and over)	Auto theft	
Murder and nonnegligent manslaughter	40	70	420	500	800	510	310	2,650
Forcible rape	40	200	380	380	810	540	320	2,670
Robbery	50	70	800	250	1,400	730	370	3,670
Aggravated assault	40	80	410	400	710	600	400	2,640
Burglary	40	80	560	250	1,500	900	280	3,610
Larceny ($50 and over)	30	60	430	160	1,100	700	310	2,790
Auto theft	30	70	330	150	1,100	650	400	2,730

[1] Based on calculations performed with the overall criminal justice system model with feedback loops.

criminal justice system over the life of the offender for processing him. A simulated sample of 1,000 offenders, arrested for the first time at age 16,[86] was taken for each Index crime category, and the rearrest patterns over the Index crimes were computed using the rearrest matrix of probabilities which were given in table 11. The resulting criminal career patterns given in table 13 were derived. For example, 1,000 offenders arrested initially for robbery would accumulate during their lives: 50 arrests for murder, 70 for forcible rape, 800 more for robbery, 250 for aggravated assault, 1,400 for burglary, 730 for grand larceny, and 370 for auto theft—a total of 3,670 rearrests for Index crimes alone.

On the basis of these criminal career pattern results, the criminal-career costs were calculated to be about $12,000 per individual,[87] representing about 3 to 4 arrests for Index crimes per offender. This demonstrates the value of an investment in preventive programs that would avert criminal careers.

The model can also be used to examine the differences between the types of crimes for which first offenders are arrested and those for which repeaters are arrested. An example of such an examination is shown in table 14. The results are tabulated according to the order of seriousness used by the FBI in the UCR.

A typical distribution of 1,000 first arrests for Index offenses was taken. The criminal careers of these 1,000 individuals were then simulated by cycling through the model, taking the probabilities of rearrest over time, and the distribution among the Index crimes of each group of rearrested persons broken down according to the crime for which they were rearrested. The simulation showed an eventual accumulation of 3,010 subsequent arrests. These include a greater proportion of the more serious offenses than the 1,000 original offenses. For example, homicides, rapes, and robberies were several times more prevalent among the rearrests than among the first arrests. The less serious Index crimes of larceny and auto theft, on the other hand, became less prevalent.

Table 14.—Average Distribution of First Arrests and Lifetime Rearrests for Index Crime Offenders

Offense	First arrests		Lifetime rearrests		Percent change in proportion of total
	Number [1]	Percent of total	Number	Percent of total	
Willful homicide	2	0.2	34	1.1	+450
Forcible rape	6	.6	68	2.3	+280
Robbery	33	3.3	458	15.2	+360
Aggravated assault	32	3.2	194	6.4	+100
Burglary	252	25.2	1,196	39.7	+60
Larceny of $50 and over	518	51.8	739	24.6	−50
Auto theft	157	15.7	321	10.7	−30
Total	1,000	100.0	3,010	100.0	----------

[1] The distribution of the 1,000 first arrests is based on the distribution of arrests of individuals under 18 given in the 1965 "Uniform Crime Reports."

These results, though only tentative, raise questions about why successive arrests appear to be for more serious crimes. This phenomenon may be due to the aging of the individuals, to the development of antisocial attitudes, or possibly even to reactions to treatment by the criminal justice system. It suggests the seriousness, in terms of escalating criminal conduct, of the problem of recidivism. A question to be explored is whether the rearrest probabilities and the crime-type distributions become worse for those who are processed further through the system. If that is the case, it may result either from differences among individuals who reach the various stages or from the treatment itself. Unfortunately, data to examine such basic questions do not now exist, but the questions are sufficiently important to warrant an intensive effort to collect the pertinent data, and ultimately, after hypotheses are developed, to conduct appropriate controlled experiments.

Effects of a Hypothetical Treatment Program

The first illustration above focused on costs and the second on crime control effectiveness as reflected in criminal careers. The model also can be used to compare alternative criminal justice system designs in terms of both cost and effectiveness. This third illustration examines a hypothetical treatment program in this context. Because no adequate data were available, completely arbitrary numbers and simplified assumptions representing a hypothetical program were chosen for the illustration. Once data from real programs become available, then revised realistic results can be obtained.

[86] Age 16 was chosen because the number of arrests for Index crimes peaks at this age.

[87] These estimates of current criminal career costs differ somewhat from those previously estimated by the Space-General Corp. ("Prevention and Control of Crime and Delinquency in California Final Report"; Space-General Corp.; July 29, 1965, pp. 65 ff.) largely because of several important differences in definitions. The Space-General analysis considered offenders rather than arrestees, thus necessitating fairly arbitrary estimates of the probability of not being caught after committing a crime. Furthermore, it considers repeated offenses only within the same type of crime (i.e., it used only the diagonal terms of the recidivism matrix). In addition the Space-General analysis treated repeated offenders as though they had infinite lives. This model used a probability of repeating that declined with age resulting in the limited criminal careers of 8 to 12 years. Finally, the Space-General analysis allocated all police costs, detective and patrol, to felony crimes. This model assigned only one-quarter of patrol costs to Index crimes.

Table 15.—Simulated Effects of Two Hypothetical Community Treatment Programs [1]

First Index arrest of individual at age 16 for—	Total career arrests and career costs					
	With use of current programs only		With individuals sent to hypothetical program whenever—			
			Sentenced in adult court		Arrested as a juvenile [2]	
	Arrests	Costs	Arrests	Costs	Arrests	Costs
Murder and nonnegligent manslaughter	3.6	$11,600	3.4	$11,500	2.1	$7,800
Forcible rape	3.7	9,600	3.4	9,200	2.1	5,300
Robbery	4.7	13,500	4.3	12,200	2.5	6,600
Aggravated assault	3.6	9,400	3.4	8,900	2.1	4,700
Burglary	4.6	14,000	4.3	12,900	2.5	7,500
Larceny ($50 plus)	3.8	11,900	3.5	11,800	2.1	6,700
Auto theft	3.7	11,000	3.5	10,300	2.2	5,900

[1] Persons treated in the hypothetical programs are assumed to have a ⅓ lower rearrest rate than persons not treated.

[2] The career costs in this column do not include any additional expenditures for achieving the reduction in rearrests.

The average number of career arrests and the costs of those criminal careers were calculated under three different sets of circumstances,[88] as shown in table 15:

First, conditions typifying present programs.

Second, all *sentenced adults* are assumed put into a hypothetical intensive treatment program which produces a one-third reduction in rearrest probabilities.[89] Compared to current probation, offenders remain in the new program 40 percent longer and receive four times as intensive supervision (i.e., it was assumed to cost four times as much to provide a day's supervision to an offender).

Third, instead of a new program for sentenced adults, all *arrested juveniles* are assumed to be put into a hypothetical program which produces a one-third reduction in their rearrest probabilities. To illustrate another approach to handling of costs, the additional costs of the new program are ignored in this computation. This could be done where there is gross uncertainty about the additional costs; one can still estimate the cost savings resulting from the increase in effectiveness to indicate a minimum warranted investment, but a complete cost-effectiveness analysis cannot be conducted.

In this example, the sentenced-adult program was found to reduce rearrests and career costs by about only 7 percent per offender. The value is so low because fewer than 20 percent of the adults arrested are ever sentenced and thus exposed to the new program.[90] Juveniles and the other 80 percent of the arrested adults do not have access to a program restricted to sentenced adults.

If all arrested juveniles could be treated so that there would be a reduction in their rearrest probabilities, there would be about a 40-percent reduction in average career-arrests,[91] and an associated reduction in criminal justice system costs of about $5,000 per individual treated. Thus, at least $5,000 could justifiably be spent per individual to achieve these results, and undoubtedly more considering the other advantages of the reduction in crime. These hypothetical results merely indicate that if an effective corrections program were available, it would have greater impact if it were applied earlier in the life of the individual, and at an earlier stage in the system where more people can benefit. There is no suggestion that such a program is now available.

FURTHER MODEL DEVELOPMENTS AND DATA NEEDS

The coming years will almost surely see a wide variety of innovative programs by criminal justice agencies. If these programs are accompanied by careful experiment, design, and evaluation, they will begin to provide some of the basic data needed to refine and extend the use of systems analysis and of models such as that developed by the Task Force. In turn, the development of systems analysis will increasingly suggest new alternatives and identify additional data needs and required research and experiment. In time it will begin to be possible to address with much greater accuracy questions more operationally relevant than those which were possible with this model—questions such as:

- ☐ The effects upon court and correctional caseloads and operating costs of a given percentage increase in police clearance rates.
- ☐ The effects upon court and correctional costs and workloads of providing free counsel to all arrestees.
- ☐ The effects upon costs and arrest rates in a particular state of instituting a given community treatment program for certain sentenced offenders.
- ☐ The projected workloads and operating costs of police, courts and corrections for a given number of years.
- ☐ The effects upon recidivism and associated costs of statistical techniques which permit sentencing judges to prescribe optimum treatment programs.

To undertake such analyses will require a completeness and detail of description and a level of data which will

[88] In all three cases, the population studied was made up of individuals arrested for the first time for an Index offense at age 16.

[89] It should be noted that these numbers are completely hypothetical. It is not clear how much reduction in recidivism is possible, and what resources would be required to achieve it. At present treatment may in fact have an adverse effect on some offenders.

[90] If the program were effective, changed sentencing practices directing more offenders into the program might result. Accounting for such interactions is one of the most difficult problems in using such a model to examine significant perturbations to the system.

[91] In terms of reduction in career rearrests, 1/20 reduction in rearrest probability in the juvenile program would be equivalent to a ⅓ reduction in rearrest probability in the sentenced adult program.

take many years of research to develop and which will always have elements of uncertainty.

It is therefore important that further work on total system models be undertaken in conjunction with specific State and local agencies. The work should include further methodological development such as sensitivity analysis to determine the sensitivity of the results to values of the various input parameters, examination of different cost allocation procedures, examination of the interactions among system components (e.g., effect of improved police effectiveness on sentencing decisions), and validation of the model by comparison with actual program experience. The work on the model should be supported by a comprehensive program to collect data on other relevant costs in addition to direct operating costs, and on arrest rates as a function of factors like age, economic level, and previous treatment by the criminal justice system.

Some specific present data needs have been highlighted by the work with this system model. Much of the published data are inconsistent, incomplete, and inaccurate. For example, different criminal justice agencies report their operations in inconsistent units: the police report "arrests," the courts report "cases," and corrections agencies report "offenders." These are adequate for managing the individual agencies, but preclude relating information across the system. The numbers of people processed at each stage by each agency are needed.

A major limitation of available data is that they are collected with reference to a legal taxonomy of crime, which is not necessarily relevant to many important questions concerning crime control. There are serious problems in using the available statistics for the study of police and corrections operations. The marauding assault is indistinguishable from the argument that got out of hand, the professional auto theft indistinguishable from the joyride. This data problem is severe and until uniform standards in greater detail prescribe the type of information reported and the basic definitions used, all analysis of the criminal justice system will be hobbled.

There are many important variables describing the crime, the situation, the victim, and the perpetrator, etc., that are not available but are required to characterize a crime more usefully for research, operational planning, and assessment of the crime problem. Included among these are the following:

Location of crime (e.g., home of victim, private building, public place).

Time of crime.

Nature of the victim (e.g., stranger, acquaintance, relation, organization, society generally, consenting party, provoker, accomplice; in addition, age, sex, and other personal qualities).

Loss suffered by victim (death, hospitalization, minor injury, psychological trauma, permanence of injury, value of property loss or damage, whether or not property recovered).

Nature of the offender (e.g., conspiracy, individual; in addition, age, sex, residence, economic status, and other personal qualities).

Apparent purpose of the crime (e.g., harm, gratification, economic gain, temporary use of property).

Nature of force involved (e.g., weapon, physical force against person, forced entry into premises, threat).

There are many instances in which no data at all is available. Merely improving the quality of information reported today is not going to be sufficient for analyzing the problem of crime. We know much too little about how various actions of the criminal justice system affect the number and types of crimes committed by different classes of offenders. The quantitative effect upon crime rates of administrative changes in the criminal law, in police operations, in prosecutorial policies, in court practices, and in correctional methods is largely unknown.

To remedy this situation, data are needed on recidivism (e.g., rearrest rate, reconviction rate) by type of crime and treatment accorded individuals by the criminal justice system. It is important to know how recidivism varies with how far a person travels through the criminal process (released after arrest, prosecution dropped, dismissed or acquitted at various stages in court proceedings, put on probation, paroled, discharged from a correctional institution). Rearrest rates are needed at each such point, as a function of age and other relevant demographic variables, and also related data on how persons who exit from the system after an arrest for one kind of crime switch to other kinds of crime.

Ideally, this information would be obtained by prospective studies of the criminal histories of samples of children born today. But the crime problem will not wait for that information. Retrospective studies are needed in the meantime. These would use samples of arrested persons matched by criminal career attributes, such as number of arrests for crimes of given types, number of convictions, numbers of times probation has been granted, number of incarcerations, and such personal attributes as age, race, sex, and economic status. Although a number of small studies have been undertaken to develop data for various hypotheses, much larger scale and more exhaustive efforts are needed.

In interpreting these data, care must be exercised to avoid interpreting spurious correlations as causes. For example, if data showed that rearrest rates do increase as offenders are processed further into the system, it might be concluded that processing through the later stages causes this increase. It may be that rearrest rates increase because offenders who are processed farther into the system are more criminal. The assignment of cause requires carefully controlled experimentation. This difficulty of interpreting results from retrospective studies is an important reason for using samples of matched offenders.

About the only data now available from controlled experiments relates to the effects of some experimental rehabilitation programs upon recidivism. Even these are limited by "Hawthorne effects"—the changes in behavior created merely by the awareness of participating in a special experimental program. Furthermore, treatment personnel in experimental programs tend to be far more competent and more motivated than the average. It is important to be able to estimate what will happen when the program is placed in the hands of the ordinary staffs.

One way to develop the needed data would be to keep detailed records on a large sample—perhaps 20,000—of those arrested in a particular jurisdiction, following them as they are processed through the police, courts, and corrections agencies. Data would be recorded on the costs incurred, the delays experienced, and the proportion following each route through the process as a function of the type of crime committed and characteristics of the individual, including age, previous record, economic status, type of counsel, etc. These data should then be related to the future criminal activity of this cohort of arrestees to estimate recidivism probability as a function of treatment by the criminal justice system.

In summary, five basic requirements for improved data collection have been identified:

Accurate and complete data on all system-related events from arrest through release are needed to describe the operations of the various agencies of police, courts, and corrections.

Each event in police, court, and corrections operations should be related to the number and characteristics of the offenders involved in it. Data should be collected on the number of arrests and charges processed by the police and the number of offenders arrested and charged. Similar data should be collected on the number of cases at each stage in court proceedings and the numbers of defendants in these cases.

The rearrest rates at each system exit point should be estimated as a function of age, sex, and other personal attributes. The probabilities that released offenders will switch among the various types of crime on rearrest should be obtained for each exit point.

Retrospective studies of criminal careers of samples of matched offenders should be undertaken as soon as possible to tap available sources of data.

Prospective studies of cohorts of juveniles and offenders released at various stages should be started now so that the limitations of retrospective studies can be overcome in the future.

While collecting and processing such a large amount of data is clearly a difficult task, it is well within the capabilities of today's technology and will be considerably aided by the development of a national criminal justice information system.

Chapter 6

Criminal Justice Information Systems

THE NEED FOR BETTER INFORMATION CAPABILITIES

The importance of having complete and timely information about crimes and offenders available at the right place and the right time has been demonstrated throughout this report and, indeed, throughout the Commission's work. With timely information, a police officer could know that he should hold an arrested shoplifter for having committed armed robbery elsewhere. With a more detailed background on how certain kinds of offenders respond to correctional treatment, a judge could sentence persons more intelligently. With better projections of next year's workload, a State budget office would know whether and where to budget for additional parole officers.

Modern information technology now permits an assault on these problems at a level never before conceivable. Computers have been used to solve related problems in such diverse fields as continental air defense, production scheduling, airline reservations, and corporate management. Modern computer and communications technology permits many users, each sitting in his own office, to have immediate remote access to large computer-based, central data banks. Each user can add information to a central file to be shared by the others. Access can be restricted so that only specified users can get certain information.

Criminal justice could benefit dramatically from computer-based information systems, and development of a network designed specifically for its operations could start immediately. Such systems can aid in the following functions:

Police patrol.—Enabling a police officer to check rapidly the identification of people and property against a central "wanted" file.

Crime investigation.—Providing a police officer or detective with supporting information files such as crime patterns, modus operandi, criminal associates, and perhaps in the future, the ability to match latent fingerprints from a crime scene against a central fingerprint file.

Police deployment.—Altering police deployment in response to changing patterns of crime on an hourly, daily, seasonal or emergency basis.

Sentencing and correctional decisions.—Providing more complete history of an offender and his reactions to prior correctional actions; statistical estimates of the effects of different kinds of treatment on different kinds of offenders.

Development of correctional programs.—Analyzing complete criminal case histories to evaluate the effectiveness of different programs.

Protection of individual rights.—Assuring that arrest records include court disposition, thereby presenting a fairer picture to the police and to judges; restricting access to certain criminal records after a specified period of good conduct.

Budgeting.—Collecting uniform statistics on agency operations and workloads, providing a basis for estimating personnel needs and for optimum allocation of men and dollars.

Research.—Providing a collection of anonymous criminal histories to find out how best to interrupt a developing criminal career and to achieve a better understanding of how to control crime.

Public education.—Portraying the true magnitude of the problem of crime in the United States.

The information problem has three principal dimensions:

1. Type of information:
   Inquiry information.—Facts about wanted persons or property needed on immediate recall ("on-line" in "real-time") by the police.
   Personal information.—Containing relevant background facts about people with whom the system must deal.
   Management information.—Needed by a criminal justice official on the operation of his agency to help him manage it better.
   Statistical information.—On crime, on the nature of criminal careers, and on the operations of criminal justice agencies.

2. Component of the criminal justice system:
   Police.
   Courts.
   Corrections.
3. Government level:
   Federal.
   State.
   Local, including county, city, and metropolitan area.

All combinations of these items must be considered in an integrated information system. At each governmental level, and in all system components, good statistical and management information are needed. Some of the statistical needs have been discussed in the previous chapter. Inquiry information is needed primarily by the police, especially at State and local levels. Personal information is needed for arrest, sentencing, and correctional decisions at all levels.

A major difficulty in obtaining needed inquiry or personal information today arises from the fact that it is frequently recorded in a jurisdiction other than the one in which it is needed. The mobility of offenders and narrow police jurisdictions require sharing common information banks. A stolen car or a wanted person can traverse many jurisdictions in a few hours. Criminals often leave an area where they are well known. The mobility of offenders and stolen property is evidenced by the following:

- ☐ In 1965, 18.7 percent of stolen autos were recovered outside the police jurisdiction of theft.[92]
- ☐ Over twenty thousand stolen autos were recovered under the Interstate Transportation of Stolen Automobiles Act (the Dyer Act) in 1965.[93]
- ☐ In 1965, 8,884 fugitives sought by State and local law enforcement agencies were identified by fingerprints submitted to the FBI by agencies other than the agency wanting the person.[93]
- ☐ Almost 50 percent of recent offenders in FBI files had been arrested in two or more States.[94]

These data provide important indications of the utility of information transfer, but they are only preliminary. Much more study is needed on the extent of mobility within a metropolitan area, within a State, within a region, and nationally. Furthermore, the value of various kinds of files in apprehending offenders and in deterring crime must still be determined. There must be a strong and continuing assessment of the effectiveness of information systems in criminal justice. There are now no good measures of the value of information systems, and the operating statistics on which to base such estimates are not now being systematically gathered. These data are needed to design future systems and to decide what functions they should perform. Only then can the cost of implementing various functions be weighed against their utility.

Even more fundamental is the question of the value of various information items themselves. No information system should simply put into a computer that which is now being collected. Rather, it should re-examine the information currently recorded, consider other items, and then by careful judgment, analysis, and experiment, try to ascertain what information is most important. Once a prototype installation is operating, evaluation of its performance will help highlight the critical information that should be kept and made available and the operational value in doing so.

Despite the difficulty of estimating their value or specifying their optimum information content, information systems should be developed. Experience in other applications has shown that in a new field it is more important to implement systems in a modest way to gain practical experience and understanding in operating them, using these initial installations to aid in the design of following systems.

Similarly with statistics, their precise value cannot be estimated. But understanding and analysis of other large social systems, such as the U.S. economy, developed only after good operating statistics became available for analysis.

The assessment of the value of information systems should begin immediately with ones now operating. A number of systems are now operating or being planned at each governmental level. For example:

The National Crime Information Center (NCIC) has been implemented by the FBI to provide immediate access to stolen-auto, stolen-property, and wanted-persons information nationally. It services 15 terminals initially, and will eventually be extended to all States and many large cities.

The New York State Intelligence and Identification System (NYSIIS) and the California Intelligence and Identification System plan to provide statewide services such as criminal history, fingerprint and name identification files, wanted-persons files, gun registration, modus operandi, sex and narcotics registration, and statistical information.

The California Auto-Statis and the New York State Police inquiry systems provide immediate access to stolen automobile files.

The Police Information System (PINS) of Alameda County, Calif., provides access to wanted-persons files for county and local law enforcement agencies as well as an automatic tie-in to the California Auto-Statis System for wanted vehicles.

St. Louis, Chicago, New York, and other cities have computer systems that provide information on stolen autos, stolen property, wanted persons, crimes, arrests, other management statistics, and help in police resource allocation.

Some of these systems duplicate files kept at higher governmental levels—auto files, for instance. Each agency addresses its own specific and immediate needs. To mini-

[92] "Uniform Crime Reports," 1965. The police jurisdiction of recovery would often be an adjacent jurisdiction.
[93] 1967 FBI appropriations hearings.
[94] "Uniform Crime Reports," 1965, based on a survey of about 135,000 offenders in the FBI "Careers in Crime" series, not a representative sample of all offenders, since it is biased in favor of Federal offenders.

mize this duplication and potential conflict, it would be desirable to establish some overall system structure and program of implementation. Active development to meet immediate local needs could then proceed in a more integrated way. This chapter attempts to outline such an overall program.

In developing such a program, the problems and needs for information were discussed with knowledgeable operational personnel in police, courts, and corrections agencies, and many of the organizations which have implemented some form of information system were visited. Most of the recent system studies conducted for specific agencies were reviewed.

Based on this work and with the active assistance of personnel experienced in creating information systems for this and other applications detailed information flow diagrams were developed for:

(1) The operational information flow in a large municipal police department;

(2) The information interchange required between police and investigating agencies on the local, State, and Federal levels;

(3) Municipal courts and courts of general jurisdiction;

(4) Information needed within and between correctional agencies, both juvenile and adult, at the county, State, and Federal levels;

(5) The gathering of operational statistics as an analysis, evaluation, and development tool.

Examples of gross flow diagrams are presented in appendix G.[95] These can serve as starting points for many criminal justice agencies designing their own systems to meet their own needs. The flow charts are available in computer-readable form and can be used for future system function and flow analyses.

These discussions and information flow diagrams have identified a number of system functions on the basis of which the Task Force has outlined a possible system structure directed at the needs of the various levels of the criminal justice system (i.e., the local, metropolitan, and State needs), and a possible supporting national structure.

GENERAL CONFIGURATION OF AN INTEGRATED CRIMINAL JUSTICE INFORMATION SYSTEM

Since the administration of criminal justice is primarily a local and State function, a national criminal justice information system must be geared to their requirements. Fundamentally, the information system must be directly accessible to them and they must specify the information they need from other jurisdictions. This leads to a concept of a hierarchy of information interchange and information files. This approach leaves with the local implementing agencies the greatest amount of design flexibility in tailoring their own system to their unique requirements. Information to be exchanged with other jurisdictions must, however, meet minimum standards of content and format. Furthermore, reporting jurisdictions must be responsible for updating their portion of a common information pool. Only that way can the files be kept current and complete and the system not saturated with useless information.

The possible system configurations range from a highly centralized Federal system, containing all the Nation's criminal justice information with a communication link reaching every criminal justice agency, to a completely decentralized system with independent computers located at every police, court, and correctional agency. The approach recommended here relegates to the local or State levels the bulk of the information system while placing at the national level the information thought to be of significant value to a number of States and to Federal law enforcement. One version of this concept would entail several regional centers, each covering several adjacent States. A limited national system has the advantages of being easier and quicker to implement, and less costly. In addition, it could provide service to States which do not now have sufficient need for their own system, and so will not implement their own for at least several years.

Centralizing too many of the functions under Federal control has the strong danger of excessive Federal control of State operating responsibilities. Hence, the assignment of Federal functions must be done with considerable caution, perhaps under the guidance of an advisory committee sensitive to these problems and to the needs of local law enforcement.

Local and State participation in the national criminal justice information system must be optional. Those that do choose to participate, however, will have to meet minimum standards of data format and content to permit the accurate transfer and interpretation of records. The total effectiveness of this system, of course, is based on having a large segment of the criminal justice community participating.

The general form of a possible national information system is shown in table 16. At the national level, there could be a central inquiry system. It would respond within seconds or minutes to police queries from anywhere in the Nation. It would include files of stolen autos, licenses, guns, and serialized or otherwise identifiable valuable property. In addition, it would list the names and identification of persons wanted for extraditable offenses. Such a system is now being operated on a trial basis by the FBI.

Personal information about adults with criminal records would be included in a *directory* which lists the formal matters of record of contact with criminal justice agencies. Dates and places of arrest for serious crimes, court disposition, sentence, correctional assignment, probation and parole would be recorded. More detailed information would be available from the local agencies. Records of persons with no recent arrests[96] could be

[95] Detailed diagrams for generic operating agencies are in "Flow Diagrams for Criminal Justice Information Systems," a report now in preparation. The report will be available from the Clearinghouse for Federal Scientific and Technical Information of the National Bureau of Standards.

[96] Decisions must be made on the minimum duration since the last contact with criminal justice agencies that warrants transferring records to the secure file. This time would depend on the types of crimes and the extent of the record.

Table 16.—Users of Files in an Integrated National Criminal Justice Information System

	Type of file			
	Inquiry	Personal information		Statistics
		Directory[1]	Registry[2]	
Required response time.	Minutes	Hours	Days	Weeks.
National	Police	All criminal justice agencies.	No file kept	Criminal justice agencies, research projects, Government public information offices.
State	do	do	Courts and corrections only.	Do.
Local	do	do	do	Do.

[1] Index of record information as to formal contacts with criminal justice agencies.
[2] Collection of related background materials (probation reports, educational records, etc.) kept by some States.

placed in a more secure file, accessible only for investigation of the most serious crimes.

Access to the national directory will normally be by means of a set of fingerprints, using either the present manual techniques or future automated techniques that might be developed. In the future it may be possible to add latent fingerprints and a repetitive offender subfile accessible by other investigative data such as a name, personal appearance, and modus operandi.

Finally, a National Criminal Justice Statistics Center should be established in the Department of Justice. The center should be responsible for the collection, analysis, and dissemination of two kinds of data:

- Those characterizing criminal careers, derived from carefully drawn samples of anonymous offenders. For specific studies, more detailed data on samples of individuals could be drawn from the States.
- Those on crime and the system's response to it, as reported by the criminal justice agencies at all levels.

The Science and Technology Task Force collaborated with the Task Force on Assessment of Crime in developing a program for a National Criminal Justice Statistics Center. The proposal is detailed in full as chapter 10 of the Assessment Task Force volume.

At the State level, an inquiry file similar to the national file would be maintained. The State file would be more extensive, however. It would include other kinds of files—motor vehicle registrations and gun registrations, for example—and would have a lower threshold of seriousness—persons wanted for nonindictable offenses, less valuable stolen property, etc.

A State would also have a directory recording a person's contacts of record with the State's criminal justice agencies. Here, too, the threshold would be lowered to include offenses not serious enough for the national directory.

In addition, to support court and correctional decision-making some States could establish more detailed records on persons in their directories. This *registry* could contain such background information as education, employment, military service, and probation reports. Such files could also be used to provide basic data for assessing the effectiveness of the State's different correctional programs. Because of the sensitivity of much of the information in the registry, its use should be restricted only to court or correctional agencies.

Much smaller and simpler information systems could be established for county courts to process court management records, to keep track of prisoners awaiting trial, to handle the probation office's information, and to provide access to State files for aid in preparing presentencing reports. This system might be integrated with local police, county sheriff, or other county management functions.

In large cities and metropolitan areas, police information systems would be established to provide access to State and national inquiry systems, to record crime and arrest reports, and for analysis of crime patterns, resource allocation, and other local management functions. In a metropolitan area, the system could be operated by a joint authority serving all the associated communities or by the core city police department offering services to the neighboring police departments on a fee basis.

IMMEDIATE RESPONSE INQUIRY SYSTEMS

A police officer frequently needs to know, within a matter of minutes, whether individuals or vehicles or other property, are wanted within his jurisdiction or elsewhere. This information must be available rapidly—within 1 to 5 minutes—to minimize the time he spends and the inconvenience to the detained person. Other information, which may not be needed so quickly, could similarly be made available.[97] This includes vehicle and firearm registrations, crime reports, and missing person reports.

An inquiry system could also support crime investigations. One of a small group of frequent serious offenders could be identified in response to an inquiry of name, aliases, personal appearance, modus operandi information, or other known characteristics revealed in a crime investigation. The design and use of such a file must be carefully considered to assure that the queries and the individuals' descriptors are complete enough to produce only a small number of responses to an inquiry.

Table 17 lists various files that might be maintained in inquiry systems. As indicated on the table, different information would be retained at each governmental level. The required time to respond to an inquiry would also be different for each kind of file.

Separate statewide inquiry systems could provide immediate information on stolen property and persons wanted within the State. An automobile recovered with its proper license plates could be checked against the State in which it is registered. For other property and for

[97] As more information is passed between the officer on the street and a central file, the need for more radio spectrum, discussed in chapter 3, will become even more pressing.

Table 17.—Possible Inquiry Files

File contents or function	Criteria for entry into file at each governmental level			Required response time to inquiry
	National	State	Local, county, metropolitan	
Stolen auto[1]	After 24 hours	Immediately	Immediately (maintained if there is no State system).	Less than 5 minutes.
Unrecovered stolen vehicles.				
Unrecovered identifiable stolen auto parts.				
Stolen auto license plates.				
Vehicles wanted in connection with felonies	Immediately.			
Stolen identifiable property[1]		All significant items not in national system.	Low valued or "special interest" items.	Do.
Individually serial numbered items.	Value greater than $1,000.			
Multiple serial numbered items.	Value greater than $5,000.			
Serial numbered items related to "serious" crimes or indication of interstate movement.	Discretion of reporting agency.			
Stolen/lost guns[1]	All reported			Do.
Serial numbered weapons.				
Weapons recovered in connection with unsolved crime.				
Wanted persons[1]	Federal warrant outstanding	Reporting agency not willing to extradite (does not include traffic warrants).		Do.
Warrants and wanted-persons notices.	Reporting agency willing to extradite.			
"Temporary felony want" (prompt action required prior to warrant (good for 48 hours only)).				
Aliases.				
Warrant file administration (felony, misdemeanors, traffic, civil, record of "attempts to serve").			All warrants	Less than 15 minutes.
Stolen auto and wanted-persons "hot sheets"		For state police or highway patrol.	For local patrol officers and detectives.	Once per shift.
Repetitive offenders	Associated with some serious, repetitive, mobile offenders in the national directory.	Associated with serious, repetitive offenders in State directory.		Less than 15 minutes.
Name index.				
Personal appearance.				
"Modus operandi" (tentative identification on basis of name, aliases, personal appearance, characteristics of crime, and other characteristics or descriptors).				
Criminal associates (list of known criminal associates).				
Access to State motor vehicle registration (identification of owners by vehicle identifiers).		All registrations		Less than 5 minutes.
Firearm registry		All registered firearms		Less than 15 minutes.
Fraudulent documents, "trademarks" of fraudulent documents (checks, bonds, stocks, etc.).		All reported documents		Do.
Names used on fraudulent documents (tentative identification of persons responsible).				
Missing persons (assist in identification and location of missing persons).		All reported persons		Do.
Sex and narcotics (directory of sex and narcotics offenders)		All persistent offenders		Less than 2 hours.
Crime reports (all pertinent information as source document for system files and statistics).			All recent reports	Do.
Arrest reports (all pertinent information as source document for system files and statistics).			All recent arrests	Do.
Ballistics (characteristics and "trademarks" of firearms and bullets on file).		All recorded characteristics		Do.
Correlation of wanted persons, crime, arrest, and field interview reports (as an investigative tool for retrieving and correlating all information on presence of suspects near scene of crime, crime patterns, possible suspects, "modus operandi," checks, etc).			All recent crimes and field interviews reported.	Do.

[1] These systems presently being implemented at national level by the FBI as NCIC with a nationwide teletype network.

persons, such an inquiry would theoretically have to be addressed to every State, requiring each State to implement its own system and calling for complex communications to every other State. A second alternative would be to establish a limited number of regional systems centralizing information within each region. The regions could be interconnected into a national system or could be kept separate, accepting the penalty of losing track of people or property that cross the regional boundaries. A third alternative is to establish a single national repository to which any State may address inquiries, and into which every State places information.

NATIONAL INQUIRY SYSTEM

In operating a national inquiry system, reports of stolen automobiles, license plates, and identifiable automobile parts would be entered immediately into a State file, and then transferred to a national file 24 hours later. After transfer, the State could either clear the record from its file or retain it. Automobiles wanted in conjunction with a felony would be entered in the national file immediately. Similar high thresholds would be placed on the wanted property and people recorded in the national file.

Such a national inquiry file (the National Crime Information Center—NCIC) was established on an initially limited basis by the FBI at the beginning of 1967. This file will contain records of all cars reported stolen for more than 24 hours, all persons wanted for extraditable offenses, stolen guns, and all stolen identifiable property valued at over $1,000. It is maintained on a computer, with terminals initially connected to 15 police agencies, and with plans to include all States eventually. Any agency with a terminal can enter a record into the file or inquire whether a person or property in custody is listed in the file. It will receive an answer seconds later.

The utility of a fully interconnected national inquiry file depends on the need for interstate and interregional communications and on the need to provide an inquiry capability for those States that do not establish their own files. If such a need should be established, a cost analysis (appendix H) indicates that a single central computer is more economical than interconnecting separate regional computers. This result follows from the fact that computer processing and storage costs are much greater than communications costs. It is important that the States, in assessing their own needs and developing their own computer facilities, and the FBI in operating the NCIC, seek to develop information that will provide a basis for a sound decision on the needs for and the form of a national inquiry system.

The cost analysis detailed in appendix H is based on providing national stolen auto, stolen property, and wanted-persons files. The cost and workload estimates are based on analyses being carried out for the FBI.[98] The data rate is based on crime and arrest projections from the "Uniform Crime Reports." Inquiry rate is estimated as a function of crime and arrest rates based on operating experience with similar inquiry systems in California and St. Louis. The projected monthly crime, record entry, and interrogation rates in 1970 are shown below:

	Index offenses	Entry rates	Interrogation rates
Stolen autos	60,629	57,876	254,764
Wanted persons and property	287,256	240,160	431,000
Total	347,885	298,036	685,764

These monthly average entry and interrogation rates were multiplied by a factor of four to assure sufficient capacity to handle loads at peak periods.

In operating the system, it was assumed that local jurisdictions send all their entries and interrogations to a State computer which communicates with the national file. For noncentralized inquiry systems, each national computer was assumed to update the others continuously.

Computer operation is assumed to cost $50 per hour[99] and computer storage to cost $25 per month per million characters. Communication costs are derived from GSA charges based on Telpak C and D tariffs.[100] The computer is assumed to require 1 second to process an entry or an interrogation. Communication of an entry is assumed to take 20 seconds, while the time for an interrogation (transmission and reply) is assumed to be 30 seconds.

An information processing center for each of the 48 contiguous States and Washington, D.C., was assumed located in the State capital.

Three separate computer configurations were considered:

1. A single centralized national inquiry system.
2. A national inquiry system divided into two locations.
3. A completely decentralized inquiry system (one in each State) in which each State retains the complete national file.

For each of these configurations, two cases were considered:

1. Each State transfers its stolen auto information to the national system after 24 hours and uses the national system to service all its interrogation.
2. Each State maintains its own stolen auto file and only interrogates the national system on out-of-State automobiles.

The results of the analysis are shown in table 18. The most economical system for the conditions considered is the single central system in which States maintain their own records of stolen automobiles even after they are reported to the national file. The Federal cost for such a system would be about $50,000 per month. The two-location system would cost about $20,000 more per month. These results follow from the fact that computer operating costs are far more dominant than communication costs. They also depend on an assumption that any noncentralized file is updated by each entry to permit any inquirer to interrogate the entire national file. The sizable overhead costs in maintaining multiple computer installations would be additional.

Because communications costs are so low, the total cost of the centralized system is relatively insensitive to the location of the computer. The optimum location would be Springfield, Ill., but shifting it to Washington, D.C., would raise the national costs by only about $1,000 per month—less than 2 percent.

Table 18.—Estimated Monthly Operating Costs of National Inquiry Systems[1]

Cost component	Centralized system (Springfield, Ill.)[2]		Two-location system (Harrisburg, Pa.,[6] and Denver, Colo.)[2]		Decentralized system
	Case 1[3]	Case 2[3]	Case 1[3]	Case 2[3]	
National communications	[4] $7,900	[5] $6,900	$7,100	$6,300	$126,000
National computer operations	55,100	41,500	71,800	58,200	
National computer storage	3,200	3,200	6,400	6,400	
National subtotal	(66,200)	(51,600)	(85,300)	(70,900)	(126,000)
States computer operations[7]	58,300	58,300	58,300	58,300	1,251,000
States computer storage	3,500	4,700	3,500	4,700	4,700
States subtotal	(61,800)	(63,000)	(61,800)	(63,000)	(1,255,700)
National and State total	128,000	114,600	146,600	133,500	1,381,700

[1] Estimates are for 1970.
[2] Minimum Cost Locations.
[3] Case 1: States do not maintain stolen auto file beyond 24 hours. Case 2: States do maintain stolen auto file beyond 24 hours.
[4] Add $1,200 if center is in Washington, D.C.
[5] Add $840 if center is in Washington, D.C.
[6] Washington, D.C., would cost only $50 more for communications.
[7] Includes estimates of stolen-property and wanted-persons files not maintained on national level.

[98] The data were provided by the Institute of Telecommunication Science and Aeronomy of the Environmental Science Services Administration of the Department of Commerce; National Crime Information Center Tele-Communications Study, ITSA Project Number V52362420.

[99] Based on 720 hours per month, including equipment backup and personnel costs.

[100] The value used is $262.50/month + $0.45/mile/month (for 6 100 word-per-minute duplex circuits) or $43.75/month + $0.0825/mile/month per duplex circuit (including 10-percent waste capacity).

The cost of converting manual records into a computer form would be small for an inquiry file. These are active files with relatively short lifetimes, so that over a period of 6 months to a year the files could be created even without a specific data conversion program.

There are several modifications to the postulated configurations that could give rise to noncentralized systems with operating costs comparable to that of the single centralized system:

- ☐ Each user could update his closest file (in his State or region) with the other files updated in the slack periods, late at night. This would reduce the peak demand on each of the computers, and so reduce their required operating capacity and computer costs. In this case, the cost of storage of about $3,200 per month would be duplicated at each installation.
- ☐ Each regional system would handle entries and inquiries only from its own region. This introduces the undetermined penalty of losing track of people and property that cross regional boundaries.

In either case, the economic penalties resulting from more, smaller installations and the additional fixed costs of operating the multiple installations would tend to favor the single central system.

STATE INQUIRY SYSTEMS

Since each State has its own internal structure, legal codes, registration and reporting requirements, and crime problems, each will fashion its inquiry system to its particular needs. Many States do not have the volume of criminal information to justify an inquiry system more complex than manual records and the telephone. In some States, the primary requirement comes from one or two metropolitan areas rather than from the State at large. In some areas, several States will join together into an interstate region and create a single common inquiry system.

The accuracy of the information in the national files is the responsibility of the States since the national system is a service to the States and no means are provided for verifying the information on a national level. In general, the State systems should not duplicate information available from the national file, except perhaps for automobile information. Only items above some threshold of importance should be kept nationally. States could keep the information below that threshold, e.g., stolen property worth less than $1,000, wanted persons they would not extradite, and intrastate repeated minor offenders.

In addition, States could provide access to the motor vehicle registration files. Also, some States require gun registration, sex and narcotics offender registries, fraudulent documents registries, and missing persons files. Which of these should be made available on-line requires further examination of their utility and cost.

The States would have the further responsibility of distributing within the State access to and responses from the national inquiry system.

LOCAL INQUIRY SYSTEMS

Whether cities, counties, or metropolitan areas establish their own inquiry systems depends on what the State implements. If the State system is complete, then access to the State and national system would normally be sufficient. Where there is no State system, major metropolitan areas would probably want to establish their own.

Even where there is a State system, certain routine functions might be implemented locally. These might include a local stolen property file, pawn-ticket records, a warrant file including "attempts to serve," and preparation of stolen-auto and wanted-person "hot sheets" for distribution to patrol officers and detectives.

HANDLING PERSONAL INFORMATION

THE PROBLEMS OF PRIVACY

The most delicate part of any criminal justice information system is the record of previously arrested people and accompanying information about them. Such information is valuable in making prosecution, sentencing, and correctional decisions. But whenever government records contain derogatory personal information, they create serious public policy problems:

> The record may contain incomplete or incorrect information.
>
> The information may fall into the wrong hands and be used to intimidate or embarrass.
>
> The information may be retained long after it has lost its usefulness and serves only to harass ex-offenders, or its mere existence may diminish an offender's belief in the possibility of redemption.

Heretofore, the inherent inefficiencies of manual files containing millions of names have provided a built-in protection. Accessibility will be greatly enhanced by putting the files in a computer, so that the protection afforded by inefficiency will diminish, and special attention must be directed at protecting privacy. However the new technology can create both more useful information and greater individual protection.

Some of these problems were reviewed in recent congressional hearings [101] on a Federal data bank. The hearings went into the problems of law enforcement information systems and the general problem of the protection of personal information files. The report stated:

> It seems evident that if the proposal to create a national data bank is adopted, we will have to rely only on the hope that benevolent people with benevolent purposes will operate the system. History, however, has already taught a terrible lesson illustrating exactly what can happen when large stores of information become available to nonbenevolent powerseekers.

[101] "The Computer and Invasion of Privacy," Hearings before a Subcommittee of the Committee on Government Operations (Special Subcommittee on Invasion of Privacy), House of Representatives, 89th Congress, July 26, 27, and 28, 1966, US Government Printing Office, Washington (1966).

> The risk involved now in entrusting the liberties of the American people to the men of power in the future, the names of whom we do not even know and whose benevolence we cannot presume to guarantee, is too great for us to take.[102]

However, when dealing with law enforcement data, the rights of society must also be protected. Although it warned against dangers to individual rights, the American Civil Liberties Union has also recognized the value of a crime information center. John DeJ. Pemberton, Jr., the ACLU Executive Secretary, made the following observations regarding the FBI's National Crime Information Center:

> Certain valid law enforcement purposes will be served by the creation of such a data center. Police work and crime detection can be more efficiently pursued if information concerning major crimes is readily and quickly available to law enforcement officials. In addition, such a center can serve as a source of vital statistical research on crime and police practices in the United States.[103]

However, Mr. Pemberton pointed out the dangers inherent in incomplete arrest information and information not relevant to crime control purposes, particularly with regard to political expressions and beliefs. Among other recommendations, he proposes several important safeguards:[104]

> Restricting the information content to matters of record.
>
> Restricting the dissemination to criminal justice agencies.
>
> Penalizing improper disclosure.
>
> Providing individuals access to their records and means for correcting them.

The New York Civil Liberties Union, the Vera Foundation,[105] and Committees of the Association of the Bar of the City of New York [106] also supported the use with limitations of information systems for law enforcement purposes.

The New York State Identification and Intelligence System has addressed the problems of handling personal information in a State information system:

> The system will not attempt to duplicate all of the detailed information currently stored in the individual case jacket and folder-files of participating agencies. Such information can be obtained, when it is needed, directly from the appropriate agency's files. However, the system will include adequate references to those sources, such as indications that a subject is currently on probation or parole or is confined in a particular facility.[107]

Some protection of personal files can come from technical security methods which can increase the difficulty of penetrating a system. In estimated order of increasing cost and complexity, these include:

- ☐ Assigning an identification code number to each user and each terminal and checking the validity of each inquiry. Codes would be changed periodically.
- ☐ Transmitting the information by mail or messenger if it is not required immediately.
- ☐ Keeping terminal equipment in secure locations to prevent access by unauthorized users.
- ☐ Protecting the stored files themselves by "locking" them whenever unauthorized persons have access to the system such as during computer maintenance. Dummy files could be used for maintenance and program checking.
- ☐ Scrambling or encoding transmitted information to minimize the danger from tapping of the lines.

No technical means, however, can guarantee that information will not be improperly used. There are many steps which can be taken, but every level of protection purchased has a possible countermeasure. Even if all the information and communications were fully encoded, some person or device must decode it, and that person or device might become accessible.

The dangers can be minimized only by insuring that the controlling organization is reliable and that the information recorded in this system is the minimum necessary. Research is needed to identify what information is useful in making correctional or investigative decisions, and the information collected and retained should be restricted to that material. The organization selected to manage and control the file must have the confidence of all agencies contributing information. The group will have to work closely with reporting agencies to assure that correct, uniform, and complete information is reported. They will be responsible for restricting the information to those authorized to receive it. In addition, some mechanism will be needed to handle the inevitable flow of requests for access to the file for purposes not anticipated when it is first established.

As a check on the users and manager of the file, all inquiries should be kept in a permanent record and that record audited regularly to verify the validity and handling of the inquiries. Unauthorized disclosure should be subject to serious penalty.

The audit should be by a different agency than the one operating the system. This group could also monitor the computer programs to insure that there are no unauthorized modes of access. They could also try by various means to penetrate the system as a running check on its security. These provisions are similar to those used to protect military information.

This problem still needs much more study, analysis, and judgment. Congressman Gallagher, chairman of the

[102] Op. cit., pp. 312–313.
[103] Op. cit., p. 182.
[104] Op. cit., p. 183.
[105] Op. cit., p. 159.

[106] Op. cit., pp. 180–181.
[107] Op. cit. p. 163, from a NYSIIS brochure, "Information Sharing, the Hidden Challenge in Criminal Justice."

Special Subcommittee on Invasion of Privacy, in calling for such efforts, stated:

> "We must call upon the scientific community, which is responsible for the development of this [computer] technology, to bear the equal responsibility for its control, in order to guarantee adequate protection of the freedoms we now enjoy."[108]

ORGANIZATION OF PERSONAL INFORMATION FILES

On the basis of the limited examination it was possible to undertake, it now appears that personal criminal-record information should be organized as follows:

- ☐ There should be a national law enforcement directory that records an individual's arrest for felonies and serious misdemeanors, the disposition of each case, and all subsequent formal contacts with criminal justice agencies related to those arrests. Access should be limited to criminal justice agencies.
- ☐ There should be State law enforcement directories similar to the national directory, but including less serious offenses.
- ☐ States should consider criminal justice registries that could record some ancillary factual information (e.g., education and employment records, probation reports) of individuals listed in their State directories. This information must be protected even more carefully than the information in the directories, and would be accessible only to court or corrections officers.

The national directory would be similar to an index or telephone directory. It would contain basic identification information such as name, identification number, age, and description. In addition, it would specify, for each arrest recorded, the date and jurisdiction, the charge, the court disposition, and the assignments to correctional supervision. No further background information other than these matters of record should be maintained in the national directory. Any more detailed background information would have to come from the individual agencies noted in the directory record. This requirement may pose some added inconvenience in collecting complete histories and in conducting research on criminal careers. However, the potential dangers inherent in a massive central dossier outweigh these disadvantages.

In addition to aiding criminal justice agencies directly, the directory, with names removed, represents a valuable research tool. The development of criminal careers could be studied, particularly to assess the effect of actions by the criminal justice system. More detailed background information on selected samples of offenders could be collected from the agencies identified on their records.

In establishing the criteria by which names should be entered, some lower threshold of seriousness of crime must be set. Crimes less serious than that threshold, such as minor misdemeanors, should not be recorded.

The data conversion cost to implement the national directory on a computer is large. In a study done for NYSIIS, the cost of converting the State criminal identification files averaged $4.50 per record (approximately $2,250,000 for 500,000 records). Preliminary estimates indicate that in 1970 the national identification files will contain the records of about 12.5 million persons which should be converted. This would involve, at the present state-of-the-art, a cost of $56 million. Even with the more easily read "rap sheets" and improvements in optical character readers, this cost could easily amount to $10–$20 million.

Trade-off studies must be performed to determine the optimum storage means. The low update rate (six updates in 3 months for a very active case) and the relatively slow access time required makes acceptable response times of over 2 hours. The estimated storage requirement is an average of 800 characters per record, or a total of 10 billion characters. Even at the relatively low cost of online storage in a data cell ($7.20 per million characters per month), this would involve a cost of $72,000 per month. Therefore, other means should be considered, such as offline storage and mounting or optical character storage in aperture cards.

The national directory would be similar to a current FBI service. Today, when a police department sends fingerprints to Washington, they are checked against a file of 16 million fingerprints of previously arrested and fingerprinted individuals. The police department then gets positive identification of the individual and his criminal record or "rap sheet." The process is conducted through the mail and takes about 2 weeks.

The rap sheet contains a record of all arrests that lead to the submission of fingerprints to the FBI. It is also supposed to contain the court disposition following each arrest, but this information fails to appear in 35 percent of the cases. A police department has no strong incentive for reporting dispositions after positive identification has been established. Some system of incentives should be developed to assure that the court dispositions are recorded. In addition, an individual should be able to learn the contents of his record and have access to a procedure to expunge clearly mistaken arrests, as in cases of mistaken identity or unfounded charge.

The FBI maintains a record until it learns of an individual's death, or until his 75th birthday has passed and he has not been arrested in the previous 10 years. It may be retained even longer because of the difficulty of cleaning out the files. Earlier purging—either destroying the record or putting it in a secure file to which only the most serious crimes would warrant access—would not only increase efficiency but would reduce the stigma of a stale arrest.[109]

A witness at congressional hearings claimed that "the Christian notion of the possibility of redemption is incomprehensible to the computer." Computer-stored information is easily cleaned out. By a policy of early purging of the files, computers permit restoring the notion of redemption to the existing manual files.

The primary entry into the directory would continue to be by means of fingerprints, using the present manual techniques until future automated techniques are developed. The fingerprint file would produce the individual's identification number or social security number[110] for entry to the directory. In order to permit identification and access to the secure directory in exceptional circumstances, the fingerprint file should not be destroyed when the directory record is purged. In the future, it may be possible to add latent fingerprints and repeating offender "profile" entries capable of being searched by name, personal appearance, or modus operandi.

A majority of States today maintain State identification bureaus similar to the FBI service. These States would presumably continue to maintain their bureaus until there was a more rapidly responding national directory. A number would choose to continue this service in a form modeled after the proposed national directory, particularly in order to maintain criminal records below the threshold of seriousness of the national directory.

To support decisions by courts and correctional agencies, as well as to evaluate the effectiveness of correctional programs, some States may choose to establish a more complete registry containing supplementary information such as probation reports, probation-institutional-parole history, as well as references to medical or psychiatric opinions, schooling, or employment records. This information would aid in preparing probation reports and in selecting correctional treatment. However, because of the dangers of such a file developing into a large central dossier system, there should be no national registry. If it is to be maintained at all, it should be on a State level and accessible only to court or corrections officers.

As with directories, the criteria for the entry of new records, the purging of the file, and the retirement of records from the file, are critically important questions to be addressed in the development of State registries to protect the individuals listed therein.

FINGERPRINT ENTRY TO PERSONAL INFORMATION

Since the primary entry to personal information files will be with a set of fingerprints, the speed of response will be limited by the time to transmit a set of fingerprints. The present manual system takes about 2 weeks to respond to the transmittal of a set of fingerprints, including time in the mail. The information is often needed within a few hours. Only then can it be positively determined in time whether the man is wanted in another jurisdiction, and his previous history made available to the requesting police agencies.

The turnaround time of urgently needed requests can be reduced to several hours or less by facsimile transmission of the fingerprint card to the central fingerprint file. NYSIIS has tested such transmission and found resolution and clarity adequate for full classification 85–90 percent of the time.[111] Since the transmission time is now about 10 minutes,[112] sending all 10,000 criminal prints the FBI receives each day by facsimile would require about 70 terminals operating full time. Since only a portion of the submitted prints require rapid response, a smaller number would probably be satisfactory. There should, therefore, be some such link between the national fingerprint file and at least one terminal in each State and major metropolitan area. Similarly, State files should be connected to each major police jurisdiction within the State. New York State is installing such a statewide network. Even a large city could connect its precincts to the central identification file, as has been done in Chicago.

After identification has been made with the fingerprint, the directory record can be sent to the requesting jurisdiction, via the inquiry system communication network.

MANAGEMENT INFORMATION

The basic criminal justice operations occur at the local level, and computers can help managers in their day-to-day decisions. Since these functions vary so widely, it is difficult to describe in complete detail specific systems that would be applicable to more than a few localities. However, it is in just this area that major direction, advice, and support should be provided to agencies desiring to implement information systems.[113]

A survey was made of about 40 agencies which now have operating information systems in order to identify the uses, costs, and other system characteristics.[114] Based on this survey, the range of costs of offline (noninterrogatable) police information systems was found to be $1,400 to $4,300 per month for punched card systems and $1,880 to $13,000 per month for computer systems. For online (interrogatable) computer systems, the costs were found to range from $10,000 to $30,000 per month.

A separate study was undertaken on the potential for modernizing court information systems.[115] For scheduling, case monitoring, and management statistics, the estimated total monthly costs, including personnel, for each of the 100 counties with populations of 300,000 to 1,500,000 would vary from $6,250 to $16,700. For each of the 10 counties with populations in excess of 1,500,000, the minimum cost is $18,750 per month. For smaller counties (100,000 to 300,000 population), punched card systems are appropriate with costs between $1,670 and $4,170 per month. For counties with less than 100,000 population, improved manual procedures should suffice.

Some of the uses which police departments and courts make of computer-based files are indicated below:

Police Management Information Systems

- Management statistics
  - Personnel
  - Patrol beat workload
  - Patrol performance
  - Crime occurrence by beat, precinct, etc.
  - Demands for service and responses
  - Crimes cleared and arrests
  - Inventory and maintenance
  - Personnel files
  - Budget
- Crime pattern analysis
  - Correlation of crimes by type, time, location
  - Prediction, short and long range
- Resource allocation
  - Patrol patterns
  - Beat allocation

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[108] Op. cit., p. 315.

[109] Some data indicate that 99 percent of rearrests occur within 5 years after release from the criminal justice system. Thus, only 1 percent of the people are rearrested after having gone for 5 years without an arrest.

[110] The military services are changing to the use of social security numbers as identity numbers.

[111] "System Development Plan," New York State Identification and Intelligence System; Albany, N.Y.; 1966; p. 104.

[112] Shorter transmission time can be obtained at the expense of resolution on the copy.

[113] As an initial step toward the definition, analysis, and specification of information systems to serve these functions, detailed information flow charts were developed in a computer-readable form. These are in "Criminal Justice Information System Flow Charts," now in preparation. The report will be available from the Clearinghouse for Federal Scientific and Technical Information of National Bureau of Standards.

[114] The results of this survey are reported in appendix F.

[115] This study is contained as an appendix to the Administration of Justice Task Force report.

Police Management Information Systems—Con.

- Jail population and scheduling
  - Population
  - Time in custody
  - Disposition or release
- Arrestee scheduling and control
  - Booking
  - Release or jail
  - Length of time in custody
  - Bond
- Emergency action support files
  - Gas, electric, water distribution
  - Hospitals and ambulances
  - Police emergency squads
- Emergency situation command and control
  - Contingency plans
  - Coordination with other emergency services and police jurisdictions
  - Emergency action support file

Court Management Information Systems

- Scheduling
  - Assignment of judges and courtrooms
  - Scheduling of preliminary hearing, pretrial conferences, and trials
  - Monitoring of attorney workloads and schedules
  - Status of defendants (in jail, on bail, at large, serving another sentence)
- Case monitoring and history (maintenance of docket)
  - Status and changes in charges
  - Pleadings
  - Dates of hearings or trials
  - Case dispositions
  - Status of defendants
  - Defense attorneys
  - Location of files of relevant documents
  - Assignment of counsel (court appointed counsel)
  - Notification of counsel of hearings or trial
  - Notification of jurors
  - Warrant preparation and control
  - General document preparation
- Management statistics
  - Court workload (number and length of cases, unscheduled idle courtroom time).
  - Judge workload (number and length of cases, unscheduled idle time)
  - Delays (time from when counsel ready for hearing or trial)
  - Case dispositions
  - Probation officer workload

ORDER OF IMPLEMENTING INFORMATION HANDLING FUNCTIONS

COMMUNICATIONS BASE

One major information problem in the criminal justice system is the dispersion of information with no ready means of communicating even its existence to agencies requiring the information. Thus, the first step in establishing a remote-access information system to service criminal justice agencies is the development of the basic communication networks which tie together the various users and repositories of information. The communications may take the form of voice radio, digital data links, written reports, and the mail.

Central to this communication foundation is the need for common definitions and coding and format standards. This requirement is frequently overlooked, leading to fragmented systems incapable of communicating with each other.

Once this foundation has been laid, it is then possible to incorporate specific functions as they are needed. This almost always requires a single agency responsible only for the gathering and distribution of information and for the establishment of the communications network and the information standards. Such an approach was taken by New York State in establishing its Identification and Intelligence System. This organization, which was established by special State legislation, has over the last 4 years studied the needs and feasibility of a statewide information system and developed plans leading to the eventual procurement of the operating system. Approximately $6 million will have been invested in this system through implementation of the first major computer functions, indicating the magnitude of the cost of initiating a major information system.[116]

ORDER OF IMPLEMENTATION

In arriving at a suggested order of implementing a specific information handling function, three criteria are appropriate:

- ☐ Its expected usefulness.
- ☐ The extent to which other functions depend on it.
- ☐ The relative ease of implementing it.

Implementation of police inquiry systems should ordinarily begin with files that are relatively easily entered with simple identifiers, such as wanted persons, autos, guns, and property with serial or registration numbers. Next would be large registries such as those of firearms, autos, and names of criminals and associates. Later stages would include more complex files such as modus operandi, fraudulent documents, and crime reports.

With respect to a personal information file, three important considerations dictating when to automate are:

- ☐ The choice of an efficient and economical means of storing the large amount of information (about 10 billion alphanumeric characters in the national directory).
- ☐ The cost of data conversion (a minimum estimate of $10–20 million for the national directory).
- ☐ The protection of the file from unauthorized access.

Technically, there are few difficulties, since the problem is simply one of conventional file retrieval with access based on positive identification (such as a directory number derived from a fingerprint search). Since a directory contains the least sensitive information, it requires the least protection and could be implemented first. For a registry, however, the decision of what information should be stored requires much more consideration, and the file must be better protected.

The first stage in implementing the fingerprint entry to the personal information system is the installation of a facsimile transmission network. Once a semiautomatic fingerprint recognition system is developed, probably within about 5 years, then these transmitted fingerprints would provide the inputs to that system.

The selection of management functions for implementation depends on local needs. However, the survey (appendix F) of criminal justice agencies using data processing equipment revealed that most have implemented similar functions. For police, these include personnel management and evaluation, crime and arrest statistics, patrol beat workload data, crime pattern analysis, and resource allocation. For courts, case scheduling, case monitoring, and general workload statistics predominate. In corrections, the emphasis is on personnel records and keeping track of offenders.

In the future, the information system will be used for more sophisticated processing. For example, as analysis and experimentation develop improved techniques for allocating patrol officers to precincts, developing court schedules, and predicting the consequences of correctional treatments, these can be incorporated as programs in the information system. Ultimately, it might be possible for the computer to analyze the characteristics of a particular crime to suggest possible suspects.

[116] For a description, see "A New Concept in Criminal Justice Information-Sharing: New York State Identification and Intelligence System," Alfred E. Smith State Office Building, Albany, N.Y. 12225.

THE VALUE OF INFORMATION

Justification for including functions in an information system are usually based either on the costs saved by replacing clerical labor, by the time saved in receiving the desired information, or by the increased quantity or quality of information provided. In the latter cases, it is very difficult to estimate the dollar "value" of more complete or faster information. For example, it is rarely possible to determine how much better a decision based on the improved information is than one made without it.

The problem is no easier when trying to estimate the value in terms such as reduced crime rate, increased clearance rate, or increased stolen property recovery rate. For example, many actions may influence the rate of auto theft and recovery: "lock your car" publicity programs, theft-proof features of new automobiles, and the ratio of joyriding to organized car theft. Over a 2–4 year period, one jurisdiction may experience variations of 40–50 percent in the unrecovered fraction of stolen autos. Over the 15 jurisdictions presently tied into NCIC, there is probably an overall variation in the order of at least 10 percent. This statistical fluctuation may well swamp any reduction in the unrecovered fraction which would be brought about by use of an information system. The problem is still more complicated when trying to assess the effects of correctional programs on offenders.

Despite these difficulties, it is important to assess as well as possible the contributions of new information functions. This will aid in their evaluation and will provide guidance to other agencies considering similar programs. Such an assessment requires baseline data on performance before the implementation of the new function, models accounting for other factors affecting performance, and estimates of the performance after implementation.

For example, although many officials feel that a stolen-auto inquiry file is justified, the limited operational experience with present systems is insufficient to confirm this view. Nevertheless, despite the sizeable effort being devoted to implementing such files at the city, county, State, and national levels, there appear to be no current efforts directed at a careful estimation of their value. In one or more such installations, the numbers, times, and locations of theft and recoveries should be studied both before and after an inquiry system is installed. The means of recovery must be differentiated to identify the contribution of the inquiry system.

Scientific Research and Development Program

The material in the preceding chapters is only a sampling of what may be the potential contributions of science and technology to control of crime and to the operation of the criminal justice system. While many subjects have been mentioned, only a few could be treated in depth, and even those are still only preliminary. Certain studies with raw data, such as those of court delay in Washington and criminal apprehensions in Los Angeles, must be repeated elsewhere to assess the degree to which their conclusions are generally applicable. Other studies, such as the cost-effectiveness optimization of response time reduction and the total system evaluation of alternative treatment programs, had to be conducted with hypothetical data, and real data must obviously be used. Many technological possibilities have been mentioned, but their potential contributions need further consideration, and their selection for specific applications requires prototype development, testing, and evaluation.

Many areas other than those discussed in this report are proper subjects for scientific research and technological development, and some may well have potential for equal or greater contributions to better understanding of the nature of crime and its control and to improving the effectiveness of the criminal justice system. In particular, the social and behavioral sciences, which were outside the scope of this Task Force, have major contributions to make in clarifying the relationships between crime and education, employment, residence, and other environmental variables, and in developing programs for diverting individuals from criminal activity and for rehabilitating them if prevention fails. The biological sciences may also offer important treatment opportunities. All the natural sciences might contribute to improving criminalistics techniques in various ways, and these possibilities have only been touched on here. All of these subjects should be considered as part of a major research and development program into the problems of crime and its control.

Federal initiative and support will be needed in establishing and pursuing such a research and development program. Whether it be basic research, equipment development, field experimentation, data collection, or analytical studies, the limited budgets of individual State and local criminal justice agencies cannot alone provide the necessary investment. The personnel and agencies capable of undertaking the necessary work are in short supply, and so unnecessary duplication should be avoided. Furthermore, any useful results will be of nationwide benefit. These conditions all make Federal involvement both appropriate and necessary.

A program to introduce science and technology to criminal justice must adopt a number of complementary approaches. The Federal Government should sponsor research, development, test, and evaluation (R.D.T. & E.) projects at the local and State levels, especially supporting those widely useful projects that no single agency could support alone. The Government should help criminal justice agencies get the technical support they need to incorporate the results of these projects into their operations. To infuse science and technology directly into day-to-day activities, operations research groups should be established in the larger criminal justice agencies. The program should include graduate fellowships to attract and train competent new professionals. It should provide means for more effective dissemination of results to operating agencies. Finally, to provide a base for broad research advances, a major science and technology program should be established in a research institute of the highest quality. The President's Science Advisory Committee has reviewed and supports these recommendations.

Within a period of 3–5 years, the total Federal research and development program in criminal justice might profitably reach a level of about $60 million. Such a level is in fact perhaps an underestimate of the need and potential, and would be limited primarily by the availability of competent personnel. In funding this program, the Government should support development by industry, research by scientists, tests and evaluation by criminal justice agencies in conjunction with scientific consultants, and innovation in the operation of criminal justice agencies through demonstration projects. The operational portion of the costs of demonstration projects should be borne by the agency directly. The Federal funding should include the incremental cost associated with the innovative features—costs for development, high risk, and extra planning. In addition, all demonstration projects should be accompanied by careful and independent evaluation which assesses the utility of the project to provide guidance for further development of that project and for other agencies considering similar ones.

RESEARCH, DEVELOPMENT, TEST, AND EVALUATION PROGRAM

The Federal Government should sponsor a science and technology R.D.T. & E. program with three primary components: systems analysis, field experimentation, and equipment-system development.

The *systems analysis* studies should include development of mathematical models of the criminal justice system and appropriate component parts, and collection of the data needed to apply these models to improving operations. The projects to be undertaken should include:

- ☐ Model of a State criminal justice system.
- ☐ Apprehension studies in a police department.
- ☐ Computer simulation of court processing of cases.

These studies would be extensions of the initial efforts undertaken by the Science and Technology Task Force. As the program develops, new problem areas in which systems analysis can be usefully applied will appear, and some of them may well turn out to be more productive than the ones already identified.

Field experimentation should be conducted by operating criminal justice agencies in conjunction with individuals or groups competent in experimental research. Many operating innovations are possible, and these should be evaluated in actual use both to test their value and to assess their possible side effects. The experimental projects to be undertaken should include:

- ☐ Controlled experiments examining various police patrol concepts, such as statistical techniques for allocation of patrol forces, various random patrol patterns, saturation patrolling, etc.
- ☐ Laboratory simulation of various police command and control systems and procedures.
- ☐ Statistical analysis relating recidivism to offender characteristics and to correctional treatment possibilities.

These areas, again, are only suggestive. Many more may be discovered by the criminal justice agencies themselves in their process of self-examination and innovation.

A number of basic kinds of *equipment* should be developed for general use by criminal justice agencies. Some of the promising possibilities include:

- ☐ Computer-assisted police command and control system.
- ☐ Fingerprint recognition system.
- ☐ Inexpensive portable radio for foot patrolmen and for patrolmen operating away from their car radios.
- ☐ Automatic patrol car locator.

The R.D.T. & E. program would have to be developed in detail by the office administering it. The program would have to be housed in an agency that was sympathetic to research and development, and could attract the high-caliber scientific staff needed to manage the program.

The program would inevitably require technical guidance of a breadth and quality exceeding that which could be expected of any internal technical staff. Advisory committees comprising scientists and criminal justice officials would be needed to review proposals in specific subject areas. In many cases, another government office will be the best choice to manage a specific project; the Army Materiel Command might direct the development of a portable radio, for example. Nonprofit or profitmaking contractors, as used by the Department of Defense, might furnish broad technical guidance.

The research grant part of the program should rely heavily on proposals submitted by scientific investigators, primarily at universities, but also at nonprofit corporations, in industry, government, and criminal justice agencies. The in-house staff should stimulate important proposals by competent researchers. Proposals should be selected for support by a series process of screening by the in-house staff, review by advisory groups combining criminal justice officials with competent researchers, and final determination by the in-house staff.

The development part of the program will have to focus its efforts more carefully. Equipment development can be very expensive, and for the next few years only a few major projects will be possible. The projects selected should not depend on the chance that appropriate proposals will be submitted. Rather, requirement studies and cost-effectiveness analyses should be undertaken, and those developments that appear to contribute most to controlling crime and to improving the operations of criminal justice agencies should be funded.

The results of the R.D.T. & E. program should be disseminated both throughout the interested research community and to all persons in the various criminal justice agencies who might benefit from the work. Journals directed at each of these audiences should be supported or new ones established if existing ones are found inadequate.

TECHNICAL SUPPORT AND ESTABLISHMENT OF EQUIPMENT STANDARDS

As the Federal Government plays a more important role in aiding criminal justice agencies to share in the products of modern technology, it will become necessary to help them use it effectively. To this end, there will be a need for centralized establishment of technical standards (for radios, computer codes, etc.) and for provision of technical assistance and guidance.

A Federal agency should be assigned to coordinate the establishment of standards for equipment to be used by criminal justice agencies, and to provide those agencies with technical assistance. This organization should be an adjunct to an existing Federal agency already technically strong and familiar with standardization problems. The National Bureau of Standards is one such agency. It could organize committees of users and manufacturers to agree on equipment and communications standards. It would be a center with growing competence in criminal justice equipment problems, and would be staffed by scientists and engineers in the most relevant technologies—electronics, computer sciences, operations research, chemistry, etc. The organization would help criminal justice agencies draw on local technical resources such as consultants, professional societies, and manufacturers, and would help the agencies to assess the products received. The assistance it offers would be a cross between that of the architect to the inexperienced home buyer and the agricultural county agent to the private farmer.

OPERATIONS RESEARCH GROUPS WITHIN CRIMINAL JUSTICE AGENCIES

As an important mechanism for innovation, the large criminal justice agencies, and especially large police departments, should establish small operations research groups with professionally trained scientists, mathematicians, and engineers, including at least one person competent in statistics. The group would analyze the operations, design and evaluate experiments, and provide general technical assistance. Such groups have proved extremely valuable to industry, government, and the military. Certainly each of the 21 police departments,[117] four sheriffs' forces,[118] and 11 State police forces [119] with more than 1,000 employees could benefit significantly from such a group. The Federal Government should encourage and support the establishment of such operations research staffs in large criminal justice agencies.

SCIENCE AND TECHNOLOGY PROGRAM IN A RESEARCH INSTITUTE

Probably the most important single mechanism for bringing the resources of science and technology to bear on the problems of crime would be the establishment of a major prestigious science and technology research program within a research institute. The program would create interdisciplinary teams of mathematicians, computer scientists, electronics engineers, physicists, biologists, and other natural scientists, and would require psychologists, sociologists, economists, and lawyers on these teams. The institute and the program must be significant enough to attract the best scientists available, and to this end, the director of this institute must himself have a background in science and technology or have the respect of scientists. Because it would be difficult to attract such a staff into the Federal Government, the institute should be established by a university, a group of universities, or an independent nonprofit organization, and should be within a major metropolitan area. The institute would have to establish close ties with neighboring criminal justice agencies that would receive the benefit of serving as experimental laboratories for such an institute. In fact, the proposal for the institute might be jointly submitted with the criminal justice agencies. The research program might require, in order to bring together the necessary "critical mass" of competent staff, an annual budget which might reach $5 million, funded with at least a 3-year lead time to assure continuity. Such a major scientific and technological research institute should be created and supported by the Federal Government.

The research institute would have to develop its own program in detail, probably with the guidance of an advisory committee comprising senior criminal justice officials and outstanding research scientists. Its program might include such subjects as: basic studies on crime (e.g., its measurement, factors related to it, and basic causes); operation of the total criminal justice system (including development of system models and collection of the needed data on costs, flow rates, recidivism, and operating policies); management of the criminal justice system (including allocation of resources, scheduling of activities, and selection, training, and evaluation of personnel); information systems (including evaluation of the value of different types of information and development of information needed to aid investigative, sentencing and correctional decisions); means for preventing and deterring crime (ranging from vocational training to intensive police patrol); police apprehension (including cost-effectiveness studies, simulation projects, and preliminary design of new equipment); criminalistics (including development and evaluation of new techniques); and offender rehabilitation (including development and evaluation of new techniques).

Research into any of these subject areas would normally require participation by several academic disciplines and most of the subjects would affect institutions throughout the criminal justice system rather than being limited to the traditional division into police, courts, and corrections. Only a major, significant institute, devoted to research on basic problems of crime and its control, could assemble the multi-disciplinary teams with the competence needed to attack these problems on the scale they demand. If the proper research environment were created, the problems of crime could draw on the nation's best scientific resources.

[117] New York, Chicago, Philadelphia, Los Angeles, Detroit, Baltimore, Washington, Boston, St. Louis, Cleveland, Milwaukee, San Francisco, Newark, Houston, Buffalo, Dallas, New Orleans, Kansas City, Seattle, Indianapolis, and Pittsburgh. (1965 "Uniform Crime Reports".)

[118] Los Angeles, Nassau, Suffolk, and Dade Counties.

[119] California, Florida, Ohio, and Texas Highway Patrols: Illinois, Maryland, Michigan, Missouri, New Jersey, New York, and Pennsylvania State Police.

PROGRAM BUDGETING FOR CRIMINAL JUSTICE SYSTEMS

by Peter L. Szanton

Budgets traditionally have been broken down by organizations—offices or bureaus—and by categories like "salaries and expenses," "office building equipment," and so forth. Such formats display *who* is spending the money, and *on what*, but they say nothing about *what for*. For many purposes, such budgets are adequate. For the analysis or management of systems, however, they are not.

An analyst wants to relate resources to purposes or objectives; a systems manager needs to assure an adequate flow of resources to accomplish given purposes. In response to those needs, new kinds of budget formats have been developed which assign resources to categories reflecting objectives or purposes rather than to the familiar administrative or accounting classifications. The categories of these so-called program budgets aggregate the expenditures of an organization—for equipment, salaries, buildings, or whatever—according to the major purpose toward which these expenditures are directed. An analyst or planner concerned with crime at the municipal level, for example, will want to know what proportion of police resources is allocated to dealing with crime, and what proportion is required for other purposes. Table A–1 suggests a format for identifying these allocations; it outlines the major purposes or "programs" of a city police department. The insertion of the appropriate cost figures for a given year next to each entry would reveal how the department's resources were being used.[1]

The insertion of figures reflecting the resources to be allocated to these purposes in future years would convert table A–1 into a program budget. All relevant investment and operating costs must be included; thus, in the subcategory "General Purpose Patrol" there should be included the appropriate fraction of the patrolmen's salaries, the contribution to their pensions, amortization of their patrol car, etc. To be most useful for planning purposes, such a budget should show the resources required for a number of future years—perhaps for a 5-year planning period.

An analyst or planner will often want not only to isolate the resources devoted to a given purpose in one organization, but also to identify the resources devoted to the same or related purposes in a variety of other organizations. To identify the governmental resources devoted to crime control in a city or State, one would need to examine the budgets of police forces, courts, jails, youth boards, and probation authorities.[2] The most useful format for this purpose would be one that combines the efforts of these various agencies according to the major programs which make up a system of criminal justice.

Table A–2 shows such a format, organized around Suppression/Apprehension, Adjudication, Correction, and Direction as the major purposes or programs related to crime. In the allocation of costs to these programs, the function being performed rather than the organizational affiliation dictates where the costs are charged. For instance, in table A–2, policemen's time in court would be charged against Adjudication, and probation investigations would be charged against Correction.

The best organization of such a budget is by no means clear. It will depend on the problems which appear most important. Thus, the tables distinguish between crimes which involve high risk of personal injury and those which do not. This breakdown will be useful for some purposes, but the analyst or manager may have other interests for which other breakdowns (e.g., felony vs. misdemeanor, crimes against persons vs. crimes against property, crimes by precinct or county, crimes by age of criminal) may be preferable. Similarly, the breakdown shown under Corrections is designed to distinguish the resources absorbed only in maintaining the custody of a prisoner from those devoted to efforts to reeducate, retrain, or counsel him. For purposes of defining the costs of various kinds of crime, however, a breakdown of correction by category of offense would be necessary. There may be other reasons for identifying the relative costs of correction by length of sentence, offender age, number of prior convictions, or other factors.

Table A–3 attempts something different. If a major Federal effort is to be made to improve the effectiveness of our systems of criminal justice, it will be important to be able to relate Federal efforts to similar State and local work. Federal programs should be designed not to duplicate local work, but to stimulate, supplement, and support it. Table A–3 is designed to identify the purpose and scale of Federal efforts in such a way as to make clear their relation to State and local activities. Like Table A–2, it is organized into the three major programs of Suppression/Apprehension, Adjudication, and Correction, plus a General Administrative category. Section A in each of these categories focuses on efforts to enforce Federal law rather than on Federal efforts designed primarily to aid the States. Even here, however, some Federal effort is in fact in aid of the States. The major purpose of many Federal criminal statutes, such as the Dyer Act, is to bring Federal resources to bear on offenders

[1] Typically, of course, existing bookkeeping systems do not present cost data in this form; they are designed to support the common categorization by organization and accounting classification. Even relatively brief examination of current books, however, by persons familiar with the organization, can often produce rough cost breakdowns in program terms. Rough breakdowns (accurate, say, to plus or minus 10 percent) can be quite helpful. Actuarial standards of accuracy are not required for many planning purposes, where larger uncertainties than these are generally present.

[2] The analysis might be expanded further. If the objective is reduction of crime over the longer term, it might be useful to identify expenditures in housing, health, education, and welfare agencies which are oriented toward the alleviation of conditions likely to cause crime, the identification of potential offenders, or similar purposes.

whose crime is essentially local, but who put themselves beyond the reach of local officials.

Section B in each of the categories outlines the various services the Federal Government might perform more directly in support of State or local police, court, and corrections systems. Not all such services need be performed expressly for the States; a Federal research program on police communications equipment, or a parole experiment conducted in the District of Columbia, for example, might be of principal benefit to States or localities even though they were also intended to serve Federal purposes.

Section C in each program category outlines the uses to which direct Federal grants to States and localities might be put. Obviously, grants may not become available for all of these purposes; indeed, they may not all be desirable. The categories used—as is true for all the tables—are designed only to be suggestive. They should be developed on the basis of local and Federal management needs.

It should be clear, furthermore, that categorizations such as these are of only limited value taken by themselves; they can simply identify in different ways the resources currently being applied to the various major objectives of criminal justice. Their greater usefulness arises when the responsible officials subject these efforts to review and analysis. The breakdown of costs into these categories then provides both a conceptual framework and a factual base for the analysis of how resources *ought* to be allocated—for considering the relative importance of the various objectives being served, the appropriateness of the current pattern of expenditures, and the benefits that might be expected from shifts in emphasis.

TABLE A-1.—A Program Budget for a City Police Force

I. CONTROL AND REDUCTION OF CRIME PROGRAM
- A. Prevention/Suppression
  - 1. General Purpose Patrol
  - 2. Special Purpose Patrol (by type of offense)
  - 3. Intelligence
  - 4. Community Relations
- B. Investigation/Apprehension
  - 1. Crimes Involving Major Risk of Personal Injury
    - a. Murder
    - b. Assault
    - c. Rape
    - d. Armed Robbery
    - e. Burglary—Homes
    - f. Arson
    - g. Etc.
  - 2. Crimes Not Involving Major Risk of Personal Injury
    - a. Theft
    - b. Unarmed Robbery
    - c. Auto Theft
    - d. Burglary—Commercial
    - e. Fraud
    - f. Forgery
    - g. Etc.
  - 3. Vice
    - a. Narcotics
    - b. Prostitution
    - c. Gambling
    - d. Etc.
- C. Prosecution
  - 1. Interrogation
  - 2. Preparation for Trial
  - 3. Trial
- D. Recovery of Property
  - 1. Autos
  - 2. Other Personal Property
  - 3. Commercial Property
- E. General Support
  - 1. Communications
  - 2. Records and Data Processing
  - 3. Technical Services
    - a. Fingerprint
    - b. Ballistics
    - c. Polygraph
    - d. Laboratory Analysis

II. MOVEMENT AND CONTROL OF TRAFFIC PROGRAM
- A. Traffic Movement
  - 1. Direction of Traffic
  - 2. Enforcement of Traffic-oriented Parking Rules
  - 3. Emergency Road Services
  - 4. Weather Emergency Procedures
  - 5. Identification and Reporting of Congestion Points
- B. Traffic Safety
  - 1. Enforcement of Regulations
    - a. Patrol/Apprehension of Moving Violations
    - b. Enforcement of Safety-oriented Parking Rules
  - 2. Driver Training
  - 3. Educational Programs
  - 4. Vehicle Inspections
- C. Accident Investigation

III. MAINTENANCE OF PUBLIC ORDER PROGRAM
- A. Public Events
  - 1. Sporting Events
  - 2. Public Ceremonies
    - a. Parades and Receptions
    - b. Public Meetings
    - c. Cornerstones, etc
- B. Minor Disturbances
  - 1. Private Quarrels
  - 2. Parties
  - 3. Drunkenness
  - 4. Derelicts
  - 5. Miscellaneous Nuisances
- C. Civil Disorder
  - 1. Prevention
  - 2. Suppression

IV. PROVISION OF PUBLIC SERVICES PROGRAM
- A. Emergency Services
  - 1. Fire
  - 2. Medical
  - 3. Power Failure
  - 4. Flood
  - 5. Civil Defense
  - 6. Miscellaneous
- B. Missing Persons
- C. Lost Property
- D. Miscellaneous

TABLE A-1.—A Program Budget for a City Police Force—Continued

V. ADMINISTRATION AND SUPPORT PROGRAM
- A. Direction and Control
  - 1. Direction
  - 2. Planning and Development
  - 3. Internal Inspection and Review
- B. Training and Personnel
  - 1. Recruitment
  - 2. Training
    - a. Basic
    - b. Advanced

V. ADMINISTRATION AND SUPPORT PROGRAM—Continued
- B. Training and Personnel—Continued
  - 3. Testing, Evaluation, Promotion
- C. Public Relations
- D. Supporting Services
  - 1. Records (noncrime) and Data Processing
  - 2. Communications
  - 3. Budget
  - 4. Property

TABLE A-2.—Programs in the Reduction and Control of Crime

I. SUPPRESSION/APPREHENSION PROGRAM
- A. Suppression
  - 1. General Purpose Patrol
  - 2. Special Purpose Patrol (by type of crime)
- B. Investigation/Apprehension
  - 1. Crime Involving Major Risk of Personal Injury
    - a. Murder
    - b. Assault
    - c. Rape
    - d. Armed Robbery
    - e. Burglary—Homes
    - f. Arson
    - g. Etc.
  - 2. Crimes Not Involving Major Risk of Personal Injury
    - a. Theft
    - b. Unarmed Robbery
    - c. Auto Theft
    - d. Burglary—Commercial
    - e. Fraud
    - f. Forgery
    - g. Etc.
  - 3. Vice
    - a. Narcotics
    - b. Prostitution
    - c. Gambling
    - d. Etc.
- C. General Support
  - 1. Communications
  - 2. Records and Data Processing
  - 3. Technical Services
    - a. Fingerprint
    - b. Ballistics
    - c. Polygraph
    - d. Laboratory Analysis
- D. Administrative Services
  - 1. Personnel
    - a. Recruitment
    - b. Training
      - (1) Basic
      - (2) Advanced
    - c. Testing and Evaluation
  - 2. Budget
  - 3. Property
- E. Planning and Direction
  - 1. Planning and Review
    - a. Data Collection
    - b. Analysis
  - 2. Direction

II. ADJUDICATION PROGRAM
- A. Prearraignment (by type of crime as in I.B.)
- B. Arraignment/Indictment (by type of crime)
- C. Preparation for Trial (by type of crime)
- D. Trial-Court Proceedings
  - 1. Achievement of Verdict or Disposition (by type of crime)
  - 2. Determination of Sentence (by type of crime)
- E. Appellate Proceedings
  - 1. Intermediate Appeal (by type of crime)
  - 2. Ultimate Appeal (by type of crime)

III. CORRECTION PROGRAM
- A. Institutional Correction
  - 1. Custody
  - 2. Correction
    - a. Education
      - (1) Academic
      - (2) Vocational
    - b. Counselling and Psychiatric
    - c. Medical and Dental
- B. Noninstitutional
  - 1. Probation
  - 2. Parole
  - 3. Work-Release
  - 4. Etc.
- C. Direction and General
  - 1. Planning and Review
    - a. Data Systems
    - b. Analysis
  - 2. Administrative Services

IV. GENERAL ADMINISTRATION PROGRAM
- A. Executive Direction
- B. Statistics
  - 1. Victim Data
  - 2. Crime Costs
  - 3. Criminal Justice System Costs
  - 4. Crime Rates
  - 5. Comparative Statistics, Other Jurisdictions
- C. Analysis
  - 1. Crime Prevention
  - 2. Allocation of Resources
  - 3. Criminal Justice System (tradeoffs among components)
- D. Programs in Mitigation of Victim Losses
- E. Administrative Services

TABLE A-3.—Federal Programs in the Reduction and Control of Crime

I. SUPPRESSION/APPREHENSION PROGRAM
- A. Enforcement of Federal Law
  - 1. Crimes—Federal in Nature
    - a. On Federal Property
    - b. Affecting Interstate Commerce
    - c. Affecting Banking System
    - d. Against the United States or Its Officers
    - e. Etc.
  - 2. Crimes—Local in Nature Made Federal Offenses in Aid of State Jurisdiction
    - a. Crimes Involving Major Risk of Personal Injury
      - (1) Murder
      - (2) Assault
      - (3) Rape
      - (4) Armed Robbery
      - (5) Burglary—Homes
      - (6) Arson
      - (7) Etc.
    - b. Crimes Not Involving Major Risk of Personal Injury
      - (1) Theft
      - (2) Unarmed Robbery
      - (3) Auto Theft
      - (4) Burglary—Commercial
      - (5) Fraud
      - (6) Forgery
      - (7) Etc.
- B. Federal Services to State and Local Police Systems
  - 1. Preventive Actions
    - a. Involving Persons: Border Control
    - b. Involving Articles: Restrictions on Entry or Shipment of
      - (1) Explosives
      - (2) Firearms
      - (3) Narcotics
      - (4) Etc.
  - 2. Training of State and Local Officers
    - a. Participation in Local Programs
    - b. Training in Federal Institutions
  - 3. Laboratories
    - a. Ballistics
    - b. Chemical
    - c. Biomedical
    - d. Etc.
  - 4. Information Systems
    - a. Stolen Property
    - b. Wanted Persons
    - c. Criminal Records
    - d. Fingerprints
    - e. Management
  - 5. Federally Conducted Research and Analysis
    - a. Deterrence Methods
    - b. Surveillance Systems
    - c. Alarm and Detection Systems
    - d. Communications
    - e. Apprehension Methods
    - f. Command and Control
    - g. Preparation of Evidence
    - h. Equipment Development
    - i. Standard Specifications Development
    - j. Technical Support
  - 6. Federal Experiments and Demonstrations
    - a. District of Columbia
    - b. Other Localities
- C. Federal Grants to States and Localities
  - 1. Special Purpose Grants
    - a. Education and Training
    - b. Local Laboratories (see B.3)

I. SUPPRESSION/APPREHENSION PROGRAM—Con.
- C. Federal Grants to States and Localities—Continued
  - 1. Special Purpose Grants—Continued
    - c. Local Information Systems (see B.4.a–b)
    - d. Research and Analysis (see B.5)
    - e. Experiments and Demonstrations (see B.5)
  - 2. General Subsidies
    - a. Capital Expenses
    - b. Operating Expenses

II. ADJUDICATION PROGRAM
- A. Federal Courts
  - 1. Crimes—Federal in Nature (see I.A.1)
  - 2. Federal Crimes in Aid of State Jurisdiction
    - a. Crimes Involving Major Risk of Personal Injury (see I.A.2.a)
    - b. Crimes Not Involving Major Risk of Personal Injury (see I.A.2.b)
  - 3. Appeals Involving State Crimes
- B. Federal Services to State and Local Court Systems
  - 1. Information Systems
    - a. Individual Criminal Records
    - b. Statistics
      - (1) Administrative
        - (a) Workload
        - (b) Elapsed Times
        - (c) Case Dispositions
      - (2) Substantive
        - (a) Sentencing Norms
        - (b) Sentencing and Recidivism
        - (c) Probation
        - (d) Parole
        - (e) Etc.
      - (3) Costs
        - (a) Correction
        - (b) Criminal Careers
  - 2. Federally Conducted Research and Analysis
    - a. Administrative
      - (1) Case Scheduling
      - (2) Jury Utilization
      - (3) Reporting
      - (4) Record Keeping
      - (5) Etc.
    - b. Substantive
      - (1) Probation Effects
      - (2) Effects of Sentences (various length and type)
  - 3. Results of Federal Experiments and Demonstrations
- C. Federal Grants to States and Localities
  - 1. Special Purpose Grants
    - a. Information Systems
    - b. Research
    - c. Experiments and Demonstrations
    - d. Education and Training
      - (1) Administrative
      - (2) Substantive
  - 2. General Subsidies
    - a. Capital Expenses
    - b. Operating Expenses

III. CORRECTION PROGRAM
- A. Federal Correction of Prisoners
  - 1. Persons Convicted of Crimes Federal in Nature (see I.A.1)
  - 2. Persons Convicted of Crimes in Aid of State Jurisdiction (see I.A.2)

TABLE A-3.—Federal Programs in the Reduction and Control of Crime—Continued

III. CORRECTION PROGRAM—Continued
- B. Federal Services to State and Local Correction Systems
  - 1. Custody and Correction of State and Local Prisoners in Federal Institutions
  - 2. Information Systems
    - a. Individual Criminal Records (post-release data on former State prisoners)
    - b. Statistics
      - (1) Parole Norms
      - (2) Parole Histories
      - (3) Recidivism Rates
    - c. Costs, Mean and Comparative
      - (1) Correction (by type of method)
      - (2) Criminal Careers
  - 3. Federally Conducted Research and Analysis
    - a. Recidivism as Function of
      - (1) Prisoner Attributes
      - (2) Method of Treatment (see 2.b.(3))
    - b. Prisoner Socialization
    - c. Prisoner Learning
    - d. Security Methods
    - e. Etc.
- C. Federal Grants to States and Localities
  - 1. Special Purpose Grants
    - a. Statistics and Analysis
    - b. Local Experiments and Demonstrations
    - c. Education and Training
      - (1) Administrative
      - (2) Substantive

III. CORRECTION PROGRAM—Continued
- C. Federal Grants to States and Localities—Continued
  - 2. General Subsidies
    - a. Capital
    - b. Operating

IV. GENERAL ADMINISTRATION
- A. Administration of Federal Programs
  - 1. Executive Direction
  - 2. Statistics
    - a. Victim Data
    - b. Crime Costs
    - c. Criminal Justice System Costs
    - d. Crime Rates
    - e. Comparative Statistics, Foreign Countries
  - 3. Analysis
    - a. Crime Prevention
    - b. Criminal Justice System (role of components, trade-offs among components)
  - 4. Programs in Mitigation of Victim Losses
  - 5. Administrative Services
- B. Federal Services to State and Local Administration
  - 1. Publication and Dissemination of Data (see IV.A.2.)
  - 2. Publication and Dissemination of Analysis (see IV.A.3.)
- C. Federal Grants to State and Localities
  - 1. Special Purpose Grants
    - a. Statistics
    - b. Analysis
  - 2. General Subsidies
    - a. Capital
    - b. Operating

A STUDY OF COMMUNICATIONS, CRIMES, AND ARRESTS IN A METROPOLITAN POLICE DEPARTMENT

by Herbert H. Isaacs

Contents

INTRODUCTION

This appendix summarizes a study conducted in the Los Angeles Police Department in August and September 1966. The study was concerned with factors affecting clearance of crimes. It traced the sequence of police activities beginning with a call for service by a citizen, the field activity of the patrol officer, the reporting of a crime, the followup investigation by detectives, and the clearance of the case by arrest of a suspect, or by other methods. Data were collected on time delays within the communications and dispatching center and on response time in the field. These data were analyzed to evaluate the effects of response time on arrest frequency, and to isolate other factors influencing the ability to solve or "clear" a crime.

The sample of 4,704 cases studied included the total crime activity in January 1966 in two of the 15 field divisions in Los Angeles. Most of the cases were responses to radio calls. The remainder resulted from field observation by the patrol force of a crime or suspicious activity. Fifteen Los Angeles Police Department officers collected the data from examination of communication message tickets, officers' daily field activity reports, crime reports, detective followups, and arrest reports. The data were coded on a standard form designed and pretested by the researchers, and then keypunched and analyzed with the aid of computer programs written for the purpose.

The substance of the report is presented in four sections below. The first is a general discussion describing the approach to the study, its objectives, and the constraints affecting the results.

The second section is an analysis of the communications center activity. By type of call, detailed breakdowns are provided of the communications center delays, field response time, and overall response time.

The third section is a discussion of arrest and other methods of clearance of crimes. A breakdown of clearance methods is given, and investigative practices and problems are analyzed.

The final section summarizes the major conclusions and offers some recommendations for further research.

GENERAL APPROACH

This research study was initially stimulated in three ways. First, there was the general intuitive feeling among many police officers and analysts exploring police problems that response time in answering a call for service is a critical operational factor. Because many aspects of technology provide an opportunity to reduce response time, it was important in the work of the Task Force to determine whether response time was a significant factor in apprehending a suspect at the scene of the crime.

Second, there was the desire to identify how the ability to solve a crime was influenced by certain characteristics of the event and the subsequent police activities.

A third stimulus for the study was less explicit: A general scientific curiosity about the nature of crime and arrest data. Significant conclusions about the operations of a system are often derived merely by collecting some specific data about the system operations, and then inspecting and analyzing that data for observable patterns.

TASKS

In conducting the study, the first task was to select an appropriate sample of police activity to study. Through the cooperation of the Los Angeles Police Department, access was gained to all recorded information available for a complete month of crime activity in two field divisions. The month of January 1966 was chosen in order to go back far enough so that arrest and detective followup reports would reflect clearance percentages that approached the total clearance rate. Also, sufficient time would have elapsed after the August 1965 riots so that the data would reflect a return to normalcy.

The two divisions selected were the University Division, with a low-to-middle income, primarily Negro population, and the West Los Angeles Division, with a middle-to-high income, primarily Caucasian population. The data used for the study began with the communications message logs for all calls for service where a possible crime was involved. We did not include drunk and vagrancy arrests, traffic incidents, and certain other calls for service, such as calls to aid injured persons, which did not appear to be crimes at the time the communications center received the call.

From the communication messages, we went to the patrol officers' daily field activity reports to determine if the radio call resulted in a crime being reported. If so, we obtained the case number and collected some information about what the officer did at the scene, if such information was recorded in his field activity report. We also scanned the field activity report for cases that did not originate with a radio call, usually field observations by the patrol officer, which resulted in a crime being reported or an arrest made. It was at this point that we also picked up any radio call cases previously neglected which were now seen to be connected with a crime. An example of such a case might be an injury call which was actually connected with an assault.

Having the case number, we were then able to go to the crime report file and retrieve the crime report, any followup made by the detectives and, if appropriate, the arrest report.

INFORMATION COLLECTED

A special coding sheet was designed to assist in the data recording process (annex 1). The items of information collected appear in each line. The numbers in parentheses next to the code categories would be circled by the officer recording the information and those circled numbers would be key-punched onto cards.

The information recorded began with the division of occurrence, the day of the month in January that the crime occurred, and a sequence number which, together with the division and date, comprised a unique serial number to identify each case for computer processing. Information was then recorded concerning the type of communications message log ticket and the type of call as viewed from the communications center (i.e., was this a suspect on scene case, a take report call, or a possible crime). We then recorded the times stamped on the communication ticket. These times included the originating time, when the call was first received at the complaint board, and the dispatch time when the dispatch order was radioed to the field unit. The difference between these two times represents the communications center delay. Occasionally there would be multiple stampings of the dispatch time because the unit first called did not respond to the call. This might occur if the unit were not available or just did not acknowledge the call. In the case of these multiple stampings, the final time stamp was recorded as the dispatch time. We also kept track of whether the call was eventually assigned to a different unit than the one originally designated.

We then examined the incoming message logs in response to each call and recorded the time of the first response by a field unit, even if it were not the unit designated to handle the call. We also noted the type of response (i.e., Code 6: "At location and investigating"; Code 4: "No further assistance," etc.). This was significant for later calculations of response time. Finally, we noted the time the case was terminated in the communications center, the time stamped on the back of the message log. To complete the record, the times from the daily field activity report indicating beginning and ending of the case as recorded by the field officer were also noted.

From examining the daily field activity report, we could then determine if a crime was reported or not. If not, we terminated the information collection. If a crime was reported because of a radio call, we then recorded some of the information available from the field activity report concerning the activities of the field officer; e.g., whether he requested a check of the vehicle license or warrant files. We also recorded any observations by the field officer shown in the activity report, and recorded the case number (the "DR number") so that we could enter the crime report, followup and arrest report files.

We noted whether an arrest was made or not, and if so, what type of charge, where it was made, the date and time of the arrest, the use by the arresting officer of prior information concerning the case, and the source of that information. We then recorded several items concerning the crime itself. These included the classification of the crime in legal terms; whether or not force or fear were involved, and certain subcategories under that heading; whether there was an attempt to take property, the dollar value reported, and the character of the item; whether the crime was inside a building, on the street, or in a vehicle; whether there was an attempt to sexually assault the victim, and related information about the relationship with the suspect; whether the suspect was seen, named or described by witness or victim; whether physical evidence was reported; whether a vehicle was used by the suspect; and detailed information on whether a followup report was made by the detectives and what actions were taken in the followup investigations.

The final information collected was an indication of whether the case was cleared by arrest or some other method; and if there was an arrest, how many suspects were arrested and how many cases were cleared by that arrest.

A computer program was developed to analyze the communications center delay time and field response time according to different categories of cases and types of calls. The program also provided a distribution of arrest delay time. In addition, the program could analyze any item or combinations of items that were coded on the basic forms shown in annex 1. It was thus possible to correlate a series of crime characteristics and analyze whether or not arrests were made or other clearances effected. It was also possible to determine some of the factors that contributed to case clearances.

CONSTRAINTS

Despite the wide variety of information collected and the ability of the analysis program to sort on any item of information, there were several constraints which limit the conclusiveness of the findings. Because of the short time period available for both data collection and analysis, the data collected were limited to historical information already available in the police department, subject to all the errors and ambiguity inherent in data not collected specifically for a statistical study.

The second constraint was the requirement to utilize many data collectors. Even though these men were officers, there were sufficient variations in their backgrounds and training so that the coding of information was not completely consistent. Furthermore, the particular orientation of these officers was toward operational situations with which they were familiar, whereas the terms used by the researchers to specify data collection were sometimes at variance with conventional operational definitions. The process of shaking down this semantic difficulty was slow and never completely successful.

A third constraint stemmed from the inherent problem of categorizing data into predefined groups. Ninety percent of the information confronted in a study falls easily into the categories designed; but the remainder presents great problems in deciding which categories are appropriate. These ambiguities are inherent in any categorization scheme, and this case was no exception. The problem was further compounded by the inability of researchers, even with a pilot study, to foresee all the requirements for detailed data which later proved to be needed.

The above constraints were recognized at the beginning of the study, and specific quality control checks were incorporated in the data collection methods. Although some errors may be found, it is not expected to have any significant effect on the conclusions.

DEFINITIONS, MEANINGS AND CATEGORIZATIONS

In order to cope with the problems of semantic orientation and categorization error, some specific conventions were adopted, recorded, and disseminated to the officers collecting the data in order to maximize the consistency of results. A complete list of these conventions is provided in annex 2. Some of the more significant ones are given below:

(1) If no actual arrest were made, the case was not coded as cleared by arrest, even if the investigator's followup listed the case as cleared by arrest. In those cases, the "other clearance" box was checked by our data collectors. This was especially important in cases where a warrant was issued but the arrest had not been actually consummated at the time of our study.

(2) Some detective followup reports were found in the file which did not indicate any actual investigative action by the detective, but merely reported supplemental information provided by the victim, e.g., adding a serial number for a stolen television, or providing a list of additional property stolen and its value. In those cases, the officers were instructed to ignore that followup report, thus limiting the followup report category to actual investigative action taken.

(3) There was a lack of followup reports in misdemeanor arrests. It was established that the department's policy was to file automatically for a complaint whenever a misdemeanor arrest was made. Hence, a misdemeanor arrest always resulted in a "yes-filing" category in the cleared-by-arrest item.

(4) Where no arrest was made, no case was actually counted as cleared in the "No. of DR's [i.e., crimes] cleared" item, even though there may have been some other method of clearance. Discrepancies in counting can be better accommodated by keeping the "other clearances" separate from the arrests.

COMMUNICATIONS CENTER ANALYSIS

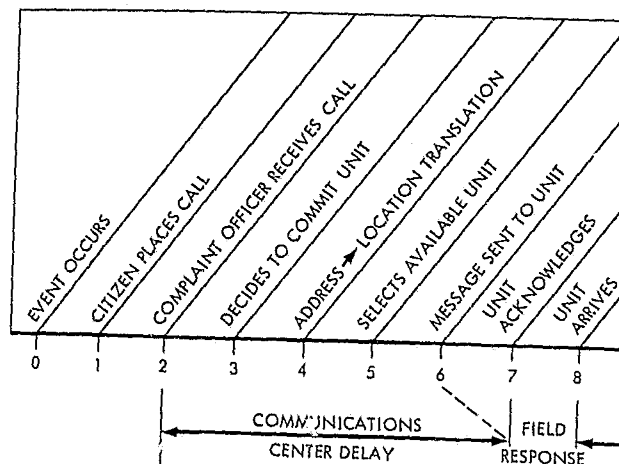
Dispatch messages within the communications center tend to be divided into two general categories: Emergency calls and nonemergency calls. These are color-coded in the Los Angeles Police Department on blue and white tickets, respectively. There is an intermediate category of nonemergency but urgent (white/Code 2). The Code 2 message instructs the patrol officer to get to the scene as rapidly as possible without using red light and siren.

From the standpoint of field procedure, a distinction can be observed in the method of handling the two groups categories of calls. The blue emergency tickets are usually answered by the closest available car, although this is often a different unit than the one assigned responsibility in the dispatching message. For the white tickets, however, whether "Code 2" or not, the unit assigned usually handles the call. Other units, even if in the vicinity, rarely appear at the scene of a nonemergency call. The major exception is when a unit in the vicinity requests to handle the call, in which case it becomes the assigned unit.

Frequently, the designated unit is either not available or quotes a delay in arriving. This causes a delay in the communications center while an alternate unit is searched out and dispatched. This is especially a problem with the white tickets, but may also affect the dispatching time of emergency calls.

The overall response time analyzed in this study consists of two major components: Communications center delay time and field response time. Figure B-1 shows eight steps in the process of responding to a call, along a time continuum beginning with the time that an event occurs. It is seen that the communications center response time, as recorded in this study, begins when the complaint officer receives the call. This time is stamped on the ticket and is what we have called the origination time. The next steps include a decision to commit a field unit, the translation of the calling address into a general geographic location, the selection of an available unit, and the sending of a message to the unit. In most cases, the time stamping for dispatch time is the time the message is sent and the unit acknowledges ("7" in fig. B-1). In emergency calls, however, units not assigned to the call may be responding as soon as they hear the message, and may actually be on their way before the assigned unit gives his acknowledgement. This is especially relevant to our calculations in cases of multiple dispatch time stamping. We have indicated the ambiguous point on the figure in dotted lines. The field response time is the remaining time between the sending of the message and the arrival of the first unit at the scene.

FIGURE B-1. RESPONSE TIME INCREMENTS



COMMUNICATIONS CENTER DELAY TIME

Table B-1 summarizes the communications center delay time results. The table gives the average delay time, the standard deviation, and number and percent of cases by type of communication ticket for three classes of calls: Those in which a single time stamp for dispatching was evidenced; those in which some delays were evidenced by multiple stamping; all calls, combining the previous two categories. Of the 4,704 total cases, 328 did not have time data, primarily because these were not initiated by radio calls. These cases were excluded from the time calculations. Table B-2 gives the same information for calls in which uncleared crimes were indicated, and table B-3 reflects cases in which arrests were made.

It can be seen from examining the tables that almost 17 percent of the calls involved multiple stamping, indicating some extra delay in the dispatching process. These extra delays result in more than twice as much time being taken in the center between receipt of a call and dispatching. For the emergency calls, less than 10 percent have extra delays associated with them, but the relative communications center delay time is much greater—as high as three times the normal emergency call delay time.

A distinct difference in communications center delay time can be seen in the handling of emergency calls as compared to nonemergency calls. Special procedures for handling emergency calls in the communications center result in reduction of the average time from 5 minutes to less than 2 minutes.

Table B-1.—Communications Center Delay Time for All Radio Calls

Type of Ticket	All calls	Single time stamp	All delays
All calls:			
Average time (minutes)	5.17	4.41	9.01
Standard deviation (minutes)	9.09	8.60	10.42
Percent cases	100.000	83.410	16.590
Number of cases	4,376	3,650	726
All code 2 and code 3:[1]			
Average time	2.11	1.70	5.33
Standard deviation	3.90	3.18	6.64
Percent cases	22.806	20.247	2.559
Number of cases	998	886	112
All white except code 2:			
Average time	6.08	5.27	9.69
Standard deviation	9.95	9.56	10.84
Percent cases	77.194	63.163	14.031
Number of cases	3,378	2,764	614
All white:			
Average time	5.89	5.11	9.44
Standard deviation	9.69	9.29	10.62
Percent cases	83.455	68.304	15.151
Number of cases	3,652	2,989	663
All blue:			
Average time	1.52	1.23	4.57
Standard deviation	3.19	2.46	6.61
Percent cases	16.545	15.105	1.440
Number of cases	724	661	63
Blue code 2:			
Average time	1.58	1.27	4.91
Standard deviation	3.27	2.53	6.78
Percent cases	15.562	14.237	1.325
Number of cases	681	623	58
Blue code 3:			
Average time	0.67	0.68	0.60
Standard deviation	0.71	0.74	0.55
Percent cases	0.983	0.868	0.114
Number of cases	43	38	5
White code 2:			
Average time	3.66	3.08	6.31
Standard deviation	5.03	4.42	6.62
Percent cases	6.261	5.142	1.120
Number of cases	274	225	49

[1] Code 2 calls instruct the officer to get to the scene as rapidly as possible without using red light and siren. On code 3 calls, the red light and siren are to be used.

FIELD RESPONSE TIME

Accurate determination of field response time is possible only in those cases where there was a "Code 6" message. This message is given by radio by a field officer when he arrives at the scene of a call. Other field responses include "Code 4," which is a message indicating that no further assistance is required at the scene, and a series of other messages, including a request for further information, the broadcast of information on the event, and other requests. However, these other responses bear little relation to actual field response time, as defined earlier.

We have therefore limited our field response time estimates to "Code 6" messages only. Unfortunately, because of the operational procedures established, only a

Table B-2.—Communications Center Delay Time for Uncleared Crimes

Type of ticket	All calls	Single time stamp	All delays
All calls:			
Average time (minutes)	6.67	5.76	11.10
Standard deviation (minutes)	9.45	8.48	12.30
Percent cases	100.000	83.036	16.964
Number of cases	1,291	1,072	219
All code 2 and 3:			
Average time	2.40	1.88	6.33
Standard deviation	4.63	3.15	9.79
Percent cases	11.929	10.534	1.394
Number of cases	154	136	18
All white except code 2:			
Average time	7.25	6.33	11.53
Standard deviation	9.78	8.86	12.43
Percent cases	88.071	72.502	15.569
Number of cases	1,137	936	201
All white:			
Average time	7.14	6.22	11.41
Standard deviation	9.69	8.76	12.35
Percent cases	91.015	74.903	16.112
Number of cases	1,175	967	208
All blue:			
Average time	1.92	1.57	5.27
Standard deviation	4.26	3.01	10.04
Percent cases	8.985	8.133	0.852
Number of cases	116	105	11
Blue code 2:			
Average time	1.97	1.60	5.80
Standard deviation	4.33	3.05	10.42
Percent cases	8.675	7.901	0.775
Number of cases	112	102	10
Blue code 3:			
Average time	0.50	0.67	0
Standard deviation	0.58	0.58	0
Percent cases	0.310	0.232	0.077
Number of cases	4	3	1
White code 2:			
Average time	3.84	2.90	8.00
Standard deviation	5.43	3.43	9.92
Percent cases	2.943	2.401	0.542
Number of cases	38	31	7

Table B-3.—Communications Center Delay Time for Cases With Arrests

Type of ticket	All calls	Single time stamps	All delays
All calls:			
Average time (minutes)	4.28	3.51	8.49
Standard deviation (minutes)	6.01	5.32	7.73
Percent cases	100.000	84.581	15.419
Number of cases	227	192	35
All code 2 and code 3:			
Average time	1.57	1.15	5.12
Standard deviation	1.81	0.89	3.36
Percent cases	33.480	29.956	3.524
Number of cases	76	68	8
All white except code 2:			
Average time	5.64	4.81	9.48
Standard deviation	6.87	6.22	8.40
Percent cases	66.520	54.626	11.894
Number of cases	151	124	27
All white:			
Average time	5.24	4.39	9.16
Standard deviation	6.55	5.90	7.94
Percent cases	76.652	62.996	13.656
Number of cases	174	143	31
All blue:			
Average time	1.11	0.94	3.25
Standard deviation	1.12	0.80	2.22
Percent cases	23.348	21.586	1.762
Number of cases	53	49	4
Blue code 2:			
Average time	1.08	0.89	3.25
Standard deviation	1.13	0.75	2.22
Percent cases	21.145	19.383	1.762
Number of cases	48	44	4
Blue code 3:			
Average time	1.40	1.40	0
Standard deviation	1.14	1.14	0
Percent cases	2.203	2.203	0
Number of cases	5	5	0
White code 2:			
Average time	2.61	1.68	7.00
Standard deviation	2.55	0.89	3.46
Percent cases	10.132	8.370	1.762
Number of cases	23	19	4

small percentage of calls result in a "Code 6" indication by the field unit. As a consequence, our field response time statistics are somewhat limited. The sample does appear to be large enough, however, to make reasonable estimates of the field response time.

Table B-4 presents a composite of all cases, uncleared crimes and arrests, where the response is given as a "Code 6" message. In examining that table, the difference in procedure in dealing with emergency and nonemergency calls is evident. The response time of the emergency calls (Code 2 and Code 3) is approximately half that of the nonemergency calls (white other than Code 2).

Table B-4.—Field Response Time[1]

Type of ticket	All radio calls	Cases with arrests	Uncleared crimes
All calls:			
Average time (minutes)	5.23	3.40	8.00
Standard deviation (minutes)	7.67	2.47	9.54
Number of cases	265	30	40
All code 2 and code 3:			
Average time	3.81	2.90	4.35
Standard deviation	5.29	2.53	3.26
Number of cases	160	21	23
All white except code 2:			
Average time	7.40	4.56	12.94
Standard deviation	9.91	2.01	12.73
Number of cases	105	9	17
All white:			
Average time	6.76	3.75	12.00
Standard deviation	9.10	2.82	12.37
Number of cases	131	16	19
All blue:			
Average time	3.75	3.00	4.38
Standard deviation	5.61	2.04	3.28
Number of cases	134	14	21
Blue code 2:			
Average time	3.78	3.00	4.53
Standard deviation	5.90	2.04	3.42
Number of cases	120	12	19
Blue code 3:			
Average time	3.43	3.00	3.00
Standard deviation	1.60	2.83	0
Number of cases	14	2	2
White code 2:			
Average time	4.15	2.71	4.00
Standard deviation	3.22	3.50	4.24
Number of cases	26	7	2

[1] Includes only cases with code 6 messages.

OVERALL RESPONSE TIME

Table B-5 presents a summary of the overall response time analyzed in the study. It is seen that the difference in response time between emergency and nonemergency calls is even further emphasized when communications center and field response delays are summed. The blue emergency calls consume considerably less time from receipt of the citizen's call to arrival on the scene. The response time for emergency calls in which an arrest is ultimately made is over one-third less than the response time for cases in which arrests are not made.

Another way to see the effect of response time on arrests is to examine how the frequency of arrest changes as response time increases. This is shown in figure B-2. In that figure, the percentage of arrests is cumulative; i.e., a point on the curve represents the percentage of arrests in all cases with response time less than the specified point. The results indicate that proportionately fewer arrests are made as response time increases.

While this evidence does not directly imply that faster response time will result in more arrests,[1] it does appear to support that view and tends to reinforce our intuition about rapid response time being significant in police effectiveness. The results of this analysis seem to imply that both communications center delay and field response delay should be minimized.

FIGURE B-2. PERCENT OF ARRESTS IN RELATION TO OVERALL RESPONSE TIME
(Code Six Responses Only)

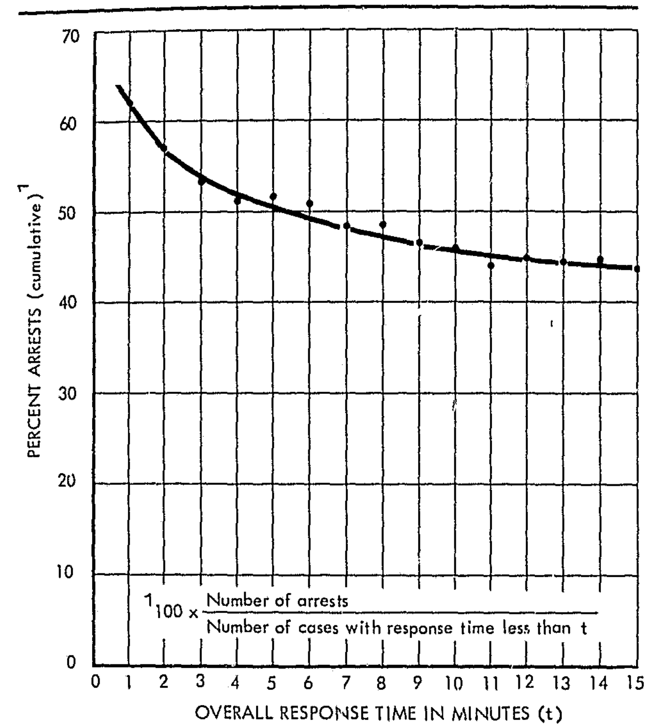


Table B-5.—Response Time and Arrests

Type of call	Average communication center delay	Average field response delay[1]	Average overall response time
Emergency (all blue):			
Crime uncleared	1.92	4.38	6.30
Arrest made	1.11	3.00	4.11
Nonemergency but urgent (white/Code 2):			
Crime uncleared	3.84	[2] 4.00	7.84
Arrest made	2.61	2.71	5.32
All other nonemergency (white not Code 2):			
Crime uncleared	7.25	[3] 12.94	[3] 20.19
Arrest made	5.64	4.56	10.20

[1] "Code 6" responses only.
[2] Very small sample.
[3] Reflects high proportion of "take report" calls.

[1] Only a controlled experiment designed specifically to test this hypothesis would be conclusive proof.

One important characteristic of minimum field response delay in an emergency radio call is the tendency of the nearest unit to answer the call, even if not assigned. If the nearest unit were assigned in all priority calls, the overall field response time would surely decrease. Also, as seen from table B-5, a significant proportion of delay is in the communications center. These observations support the use of more automated methods of call processing to reduce the communications center delay and car location to find the nearest available car.

EMERGENCY DISPATCHING CRITERIA

There is another significant result concerning response time which needs to be examined. Table B-6 provides a breakdown of the emergency and nonemergency radio calls in terms of whether crimes were reported. Table B-7 indicates for all radio call crimes the number and percent in each dispatching category that were cleared by arrest or other methods.

Examination of these tables suggests an interesting hypothesis concerning emergency dispatching criteria. First, note that the overall number of crimes reported, given a radio call, is 1,614 of 4,376 (or 37 percent). The emergency calls, however, only show 24.7 percent crimes reported. This is low primarily because of the false alarm rate for silent burglary alarms. The nonemergency cases, on the other hand, result in 40.5 percent crimes reported.

If we examine the uncleared crimes in this category, we note that 1,138 (or 83 percent) of nonemergency radio call crimes are not cleared. About 90 percent of those 1,138 are calls to take a crime report after the crime has already been committed (burglary, for example). As we will show below, this is the most difficult type of case to clear. However, of the 1,138 uncleared nonemergency calls, we have found that in 112 cases (or 10 percent), the information available at the communication center at the

Table B-6.—Radio Calls and Crimes Reported

Type of call	All radio calls	Percent of total	Radio calls with crimes reported	Percent of radio calls
Emergency (all blue)	724	16.5	179	24.7
Nonemergency but urgent (white/Code 2)	274	6.3	67	24.4
Nonemergency (other white)	3,378	77.2	1,368	40.5
Total	4,376	100.0	1,614	37.0

Table B-7.—Clearance of Radio Calls With Crimes Reported

Type of call	Uncleared crimes	Arrests made	Other clearance	Total cleared	Total radio call crimes
Emergency (all blue)	116	53	10	63	179
(Percent)	(65)	(30)	(5)	(35)	(100)
Nonemergency but urgent (white/Code 2)	38	23	6	29	67
(Percent)	(57)	(34)	(9)	(43)	(100)
Nonemergency (other white)	1,138	151	79	230	1,368
(Percent)	(83)	(11)	(6)	(17)	(10[illegible])
Total	1,292	227	95	322	[illegible]
Percent	(80)	(14)	(6)	(20)	(100)

time of the citizen's call led to the conclusion that this was a "suspect-on-scene" or "possible crime" case.

The hypothesis we are exploring is that some fraction of the nonemergency calls should really be given emergency dispatching priority. Although as a percentage of total nonemergency calls these 112 may not appear significant, they represent more than 15 percent of the number of actual emergency calls in the sample, and 63 percent as many cases as the number of emergency calls with crimes involved.

Table B-8 gives a breakdown of the types of cases we are discussing. In this sample of 112 calls, 57 cases actually appeared in the communications center to be suspect-on-scene calls. When the officer arrived, he may have been too late to do anything more than take a crime report, or the suspect might have just left, or might still have been on the scene. This total of 57 cases includes a significant proportion of serious crimes such as burglary, robbery, and aggravated assault. If we now examine the calls that appeared to the communications center to be possible crimes, we again note a number of cases of significance, including one homicide; and a series of lesser crimes, particularly a large number of malicious mischief cases.

It is clear that response time is not critical in some of these cases, especially the possible crimes which resulted in "take report" calls. But a significant proportion of these 112 nonemergency calls would have greatly benefited from decreased response time, especially the felonious crimes where the suspect appeared to be on the scene at the time of the call. In addition, there are the cases concerning husband-wife or neighbor disputes, fights or juvenile disturbances which may be initially communicated to the police by a witness who does not know the seriousness of the event (and, indeed, many of the events are not at all serious at the time of the call). Unfortunately, a number of these tend to escalate into more serious situations such as aggravated assaults.

Table B-8.—Nonemergency Dispatching Problem Calls: Breakdown of Types of Cases

Type of crime	From call information						Totals (112)		
	Appeared to be "suspect-on-scene" (57)			Appeared to be "possible crime" (55)					
	At arrival:			At arrival:			At arrival:		
	Take report	Suspect gone	Suspect-on-scene	Take report	Suspect gone	Suspect-on-scene	Take report	Suspect gone	Suspect-on-scene
Murder						1			1
Aggravated assault	3	1		1			4	1	
Sex offense		1						1	
Burglary	12	6	2	8	1		20	7	2
Robbery	1	1		1			2	1	
Grand theft	2						2		
Petty theft	3	3		1		2	4	3	2
Grand theft—auto				6			6		
Simple assault						1			1
Malicious mischief	4	4	1	23	2		27	6	1
Other	2	2	1	2	2	3	4	4	4
Unknown [1]			8			1			9
Total	27	18	12	42	5	8	69	23	20

[1] Type of crime omitted in data collected.

serious situations such as aggravated assaults.

These considerations strongly suggest the need for modified criteria for emergency dispatching. Increasing the number of calls which receive priority assignment may tend to degrade slightly the response time on existing priority assignments. Nevertheless, an examination of the false alarm rate rapidly leads one to the conclusion that the number of cases negatively affected by this change would be very small, compared to the number of cases in which improved effectiveness of the police would result. With our present knowledge of calls for service, however, it is not possible to state the specific modifications and criteria that seem to be implied by the results of this study. The criteria for assigning such priority must be developed from a research and development program with that specific objective. Such a program is outlined in the last section.

ARREST AND OTHER TYPES OF CLEARANCE

Table B-9 lists the types of crimes reflected in this study. Of the total 1,905 crimes, 482 were cleared by arrest or some other means of clearance. Before discussing the specific results, a general discussion of case clearance methods may be helpful. If an arrest is made, a complaint may or may not eventually be filed against the arrestee. If a complaint is not filed, the "other clearance" category in our coding scheme indicates one of several possible reasons. For example, the subject may be a juvenile, in which case special procedures are required. The prosecutor may choose not to file due to the lack of sufficient evidence or the victim may refuse to prosecute. Followup investigation in a case may indicate that no crime was actually committed. Finally, there may be a variety of other reasons for not filing a complaint, including the setting of a hearing by the city attorney.

Even if the suspect is not arrested, the case may be cleared in one of the several "other" ways including those just described or by issuing a warrant for his arrest.

Arrest may result in several ways. For example, in shoplifting cases, the arrest is frequently made by a security officer in a retail establishment who summons patrol officers to take the offender into custody. Arrests may also be made on the scene by the patrol officer, following his observations of criminal activity or perhaps a wanted person or wanted vehicle. Arrests may be made in response to a radio call of either the emergency or nonemergency varieties. Occasionally, a patrol officer will make an arrest at the residence of an individual who is wanted for some prior crime.

Table B-9.—Breakdown of Types of Crimes

Type	Number	Percent [2]
Murder	4	0.2
Aggravated assault	94	5.0
Rape	14	.8
Other sex	14	.8
Burglary	626	33.5
Robbery	102	5.5
Grand theft	70	3.7
Petty theft	311	16.6
Grand theft—auto	328	17.5
Simple assault	60	3.2
Worthless document	9	.4
Malicious mischief	127	6.8
Other	112	6.0
Unknown [1]	34	
Total	1905	100.0

[1] Type of crime omitted in data collection.
[2] Percent of identified crimes.

CLEARANCE DATA

Table B-10 gives a summary breakdown of arrests and other clearance. Of the 482 cleared cases, 336 actual arrests were made, 304 by patrol. It is seen that patrol officers make greater than 90 percent of all arrests. The remaining 10 percent are made by the detective force, in most cases through followup investigations of a particular crime. Although the detectives actually make very few arrests themselves, their followup investigations frequently identify wanted persons who are later the subject of patrol officer arrests. The exact number of these was not specifically collected in the study, but an approximate figure inferred from other collected data indicates that about 25 percent of patrol arrests are of individuals previously named in detective followups.

The breakdown of other clearance methods is given in table B-11. About one-third of these cases involved juveniles where some procedure other than arrest was utilized. Another third involved cases in which either the prosecutor chose not to file, the victim refused to prosecute, or later investigation indicated no crime was actually involved. The last third contains the other methods including city attorney's hearing and issuance of warrants. Initial design of data collection methods for this study did not envision such a large volume of "other" methods. As it became evident during the data collection that the "other" category was too broad, an attempt was made to sample crimes in that category to determine what the general breakdown reflected. A sample of 20 such cases of other clearance resulted in the determination that approximately two-thirds involved city attorney's hearings, and the remainder involved warrants for arrest of a suspect. In the sample of 20, only one case involved some dispositional action other than the hearing or warrant.

In examining the breakdown of types of crimes in cleared cases, some differences are apparent between arrests and other methods of clearance. Table B-12 illustrates these differences for some crimes. It is seen that the "harder" felonious crimes, such as burglary, robbery, and auto theft, tend to be cleared more by arrest; whereas the "softer" crimes, such as simple assault and malicious mischief, tend to be cleared by other methods.

Table B-10.—Cleared Cases

	Totals	Patrol	Detective	Not shown
Arrests made:				
Filing	233	206	25	2
Other clearance	103	98	2	3
Total	336	304	27	5
Other clearance, no arrest made	146			
Total cleared cases	482			

Table B-11.—Breakdown of Other Clearance

Other clearance method	No arrest	With arrest	All
Juvenile	17	61	78
Prosecutor chooses not to file	14	22	36
Victim refuses to prosecute	22	6	28
No crime	24	3	27
Other	68	11	79
Unclear	1	0	1
Total	146	103	249

Table B-12.—Types of Crimes and Methods of Clearance

Type of crime	Cases cleared by arrest	Cases cleared by other methods
Burglary	55	13
Robbery	24	2
Grand theft—Auto	42	7
Simple assault	11	37
Malicious mischief	11	13

In analyzing the characteristics of arrests, two types of data were collected: One on the charge made at the time of arrest; the second on the location of the arrest. The charge included (a) the case for which this crime report was made (coded "This DR"); (b) another case in a series of crimes committed by an individual (coded "Other DR this Series"); and (c) another charge, such as a traffic citation, which led to an arrest on the specific case involved (coded "Other Charge").

The location of arrest included (a) on-scene; (b) vicinity of a current crime; (c) the residence of the suspect; (d) other locations; and (e) unclear.

Table B-13 gives the breakdown of 304 arrests by patrol and 27 arrests by detectives according to those two addi-

Table B-13.—Breakdown of Arrests

	This DR	Other DR this series	Other charge
	Arrests by patrol		
On scene	148	4	4
Vicinity (current)	51	3	2
Residence	21	0	2
Other	50	2	5
Unclear	11	1	0
Total (304)	281	10	13
	Arrests by Detective		
On scene	4	5	0
Vicinity (current)	1	0	0
Residence	6	0	0
Other	5	1	2
Unclear	1	2	0
Total (27)	17	8	2

tional characteristics. It should be emphasized that the on-scene arrest does not imply that the patrol officer caught the suspect in the act. It merely indicates that when the arrest was made the suspect was at the location at which the crime was committed.

Relative to this last point, an analysis was made of on-scene and vicinity arrests—a total of 223 out of the 336 arrests made. Of these, 91 cases involved observations by the patrol officer of some suspicious activity. The 91 cases included 25 observations of crimes, 58 observations of individuals under suspicious circumstances, and 8 observations of suspicious vehicles.

Figure B-3 gives the delay in arrests from the time the crime is committed. Over one-third of all arrests are made in the first one-half hour. By the time 2 hours have passed, almost half the arrests have been made. These are, of course, primarily on-scene or vicinity arrests by patrol. The cumulative percentage of arrests then retards in slope until investigative action results in additional arrests being made. By the end of the first week, almost two-thirds of all arrests have been made; 94 percent by 1 month and 98.5 percent by 1 year.

In cases where arrests are made, there are frequently multiple suspects and/or multiple cases involved. Table B-14 gives the figures on number of suspects arrested per case, and number of cases cleared per set of arrests, for a sample of 262 arrests. The results indicate an average of 1.5 suspects arrested per case and 2.8 cases cleared per arrest.

Table B-14.—Average Number of Suspects Arrested and Crimes Cleared

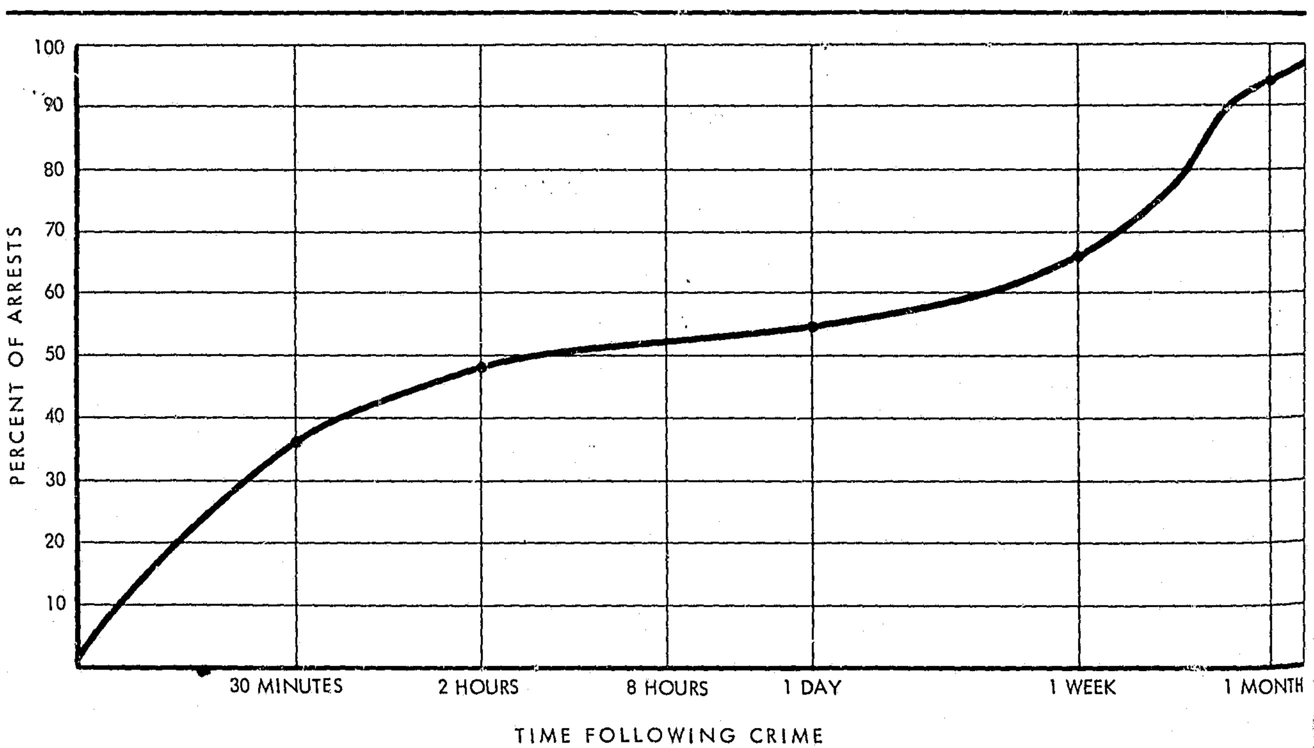
	Number counted	Cases in sample	Average per case	Standard deviation
Suspects arrested	396	262	1.51	0.89
Crimes cleared (DR's)	722	260	2.77	7.55

UNNAMED SUSPECTS

One of the most significant characteristics of a case, affecting its chances of being cleared, is whether the suspect was named in the crime report by the victim. However, before we examine the data on this characteristic, some explanation of the ambiguities involved is required.

There are really three general categories of cases concerning named or unnamed suspects. The first category is where the suspect is actually *known* to the victim. The second category is where the suspect was *not known* to the victim, but was arrested in the process of committing the crime and, therefore, directly identified at the time the crime report was made. The third category is where the suspect was not known to the victim and was not apprehended at the scene and, therefore, the crime report did not reflect the suspect's name.

FIGURE B-3. ARREST DELAY TIME



When this research study was first designed, the distinction between the first two categories was not clear. Therefore, instead of collecting information on whether the suspect was known to the victim, we recorded only whether or not the suspect was named in the crime report. In 1,905 cases in which crimes were involved, 349 were coded as "suspect named." About midway through the study, this problem was detected and a special sample was run to evaluate the relative ratio of cases in the first two categories. That special sample included 69 cases. Of these, 33 or almost half were known to the victim or witness prior to the crime being committed. Of the remaining 36 (about 50 percent), 14 (or 20 percent) were not known to the victim, but were arrested by a retail store security officer or other citizen. The remaining 22 (or 30 percent) were not known to the victim but were arrested at the scene by the patrol officer. These data help to qualify the results given below.

The "suspect named" category, as coded, includes two basic variants—one in which the name was confirmed, and one in which the name was unconfirmed at the time the report was made. The unconfirmed name, for example, might be entered if the victim suspects someone but has no evidence. In the "suspect not named" category, there are also two variants. Either the suspect was completely unknown, or some partial name or nickname was available which was not sufficient to identify him.

Table B-15 summarizes the total number of crimes, both cleared and uncleared, with named and unnamed suspects. Examination of this table shows that over 60 percent of the cleared cases are those in which the suspect was named in the crime report. As we have indicated from our special sample, about half of these were arrests on-scene of unknown suspects.

In the uncleared cases we note the high correlation with the unnamed suspect characteristic. Out of a total 1,423 uncleared cases, 1,375 concerned unnamed suspects. In considering the 48 uncleared cases with named suspects, these divide into 23 cases with unconfirmed names, and 25 cases with confirmed names. Of the 23 unconfirmed name cases, followup investigations were made in 13 of these. In only six cases was the unconfirmed name confirmed by the followup investigation. In the 25 uncleared cases coded as "confirmed name," only 6 followups were made, and only 4 of these confirmed the originally named suspect. This means that of a total of 48 uncleared cases coded as possibly having named suspects, only 29 actually were confirmed.[2]

Table B-15.—Comparison of Clearance in Cases With Named and Unnamed Suspects

	Uncleared cases (1,423)	All clearance (482)	Cleared by arrest (336)
Suspect named:			
Confirmed	25	292	----------
Unconfirmed	23	9	----------
Total (349)	48	301	203
Suspect not named:			
Completely unknown	1,366	168	----------
Partial or nickname	9	13	----------
Total (1,556)	1,375	181	133

The impact of the named suspect characteristic can be seen more specifically by examining some particular types of crimes. For example, assault cases tend to be cleared at a much higher rate than most other crimes. This is primarily because a large proportion of assaults involve named suspects. Out of a total of 154 aggravated and simple assaults, 116 (or 75 percent) were *named* suspect cases. Of the 154 assaults, 123 (or 80 percent) were cleared.

A similar result is seen in rape cases. Out of 14 total cases in this category, 10 were cleared. Nine of the 14 cases involved named suspects. Burglaries, on the other hand, generally involve unnamed suspects. Of the 626 burglaries, only 31 (or 5 percent) had named suspects. This significantly affects the clearance rate. While burglaries represent 34 percent of the total number of cases, they comprise only 15 percent of the total number of *cleared* cases.

The impact of the named suspect characteristic on clearance of crimes raises a question concerning the response time and arrest data presented previously. In attempting to insure that the named suspect problem did not bias the conclusion about the relationship between response time and arrest, the results were checked. We eliminated the named suspect cases and made calculations similar to those displayed in figure B-2. Although the sample of cases was reduced considerably, the results reinforced the previous conclusions on response time. Of the 34 total cases, 8 arrests were made, 7 of these in cases with 2-minute response time or less.

INVESTIGATIVE PRACTICE AND PROBLEMS

Table B-16 summarizes the information collected on investigative followup practice. Two intuitive observations about detective activity are supported by the information in this table.

The first observation is that detectives tend to put their energies in cases where there is something positive to investigate. Almost two-thirds of their followups in cleared cases were associated with suspects named in the crime report. Furthermore, the followups in the unnamed suspect cases, although an appreciable one-third of the total, include only a relatively small number of cases that were solved primarily by detective followup investigation. On-scene patrol arrests accounted for the clearance of more than 70 of the 136 unnamed suspect cases.[3] The followup reports made in those 70 represent only the investigation needed to request filing of a complaint against the suspect in custody. This leaves less than 66 out of 363 followups, or less than 20 percent, in which the detective effort was not initiated by knowledge of a specific suspect, either named or in custody.

Of the 1,423 *uncleared* cases, only 84 followups were actually made by detectives, and the suspect was named in

[2] One might expect that those 29 cases would have been cleared. The discrepancy is possibly attributable to errors in coding during data collection. For example, if warrants were issued for the 29 suspects, the cases should have been coded as "cleared."

[3] As noted earlier, due to differences in reporting practice, many on-scene arrests do not result in a suspect being named in the crime report.

Table B-16.—Investigative Followup Practice

	Cleared	Uncleared
Total cases	482	1423
Total number of followup reports made	363	84
Suspect named in followup report:		
Suspect named in crime report	200	12
Unnamed suspect	136	6
Total	336	18

only 18 of these. This does not imply necessarily that the detectives work only on cases which can be cleared. But it does imply that detectives do not make followup reports when there is nothing to report. To put it another way, the bulk of the 1,423 uncleared cases had little or no evidence on which detectives could base a followup investigation.

Detectives also appear to allocate their efforts according to the value of the case. Table B-17 shows the difference in average property value for cleared and uncleared cases in which property was taken. It can be seen that the average value in cleared cases is significantly higher than in the uncleared ones. Furthermore, the cleared cases having detective followups tend to be even higher.[4]

Tables B-18 and B-19 examine some of the methods by which suspects are linked with cases in the detective followup reports. As we noted, many such linkings are initiated by on-scene arrests made by patrol officers, rather than as a result of followup investigation.

Table B-18 summarizes the total number of unnamed suspect cases in which particular methods were used. These methods include identification of suspects from photos, modus operandi techniques, stolen property,

Table B-17.—Clearance and Property Value

	Cleared cases	Uncleared cases
Total cases	482	1,423
Cases with property stolen	150	846
Total value	$83,944	$328,662
Average value	$555	$388
Standard deviation	1,954	1,324
Followup made	115	61
Total value	$75,521	$20,718
Average value	$651	$338
Standard deviation	2,147	705

Table B-18.—Methods for Linking Unnamed Suspects to Crimes

Method used: [1]	Number of cases
Photo identification	12
Modus operandi	6
Stolen property	36
Weapon	2
Vehicle	33
Interrogation of arrestee	48
Other [2]	41
Total cases of suspect not named in crime report but named in detective followup report	134

[1] May use more than one in each case.
[2] Large proportion of "other" are personal identification by victim or witness.

Table B-19.—Followup Methods and Types of Crimes

Method	Selected types of crimes: Aggravated assault	Burglary	Robbery	Petty theft	Grand theft—auto
Photo:					
Unique method	0	0	3	0	0
In combination	1	2	4	0	1
Modus operandi:					
Unique method	0	1	0	0	0
In combination	0	3	0	0	0
Property:					
Unique method	0	5	0	0	2
In combination	0	7	7	3	9
Weapon: [1]					
Unique method	0	0	0	0	0
In combination	0	0	0	0	0
Vehicle:					
Unique method	0	1	0	0	1
In combination	0	6	3	2	13
Interrogation:					
Unique method	1	8	2	0	3
In combination	1	11	6	5	5
Other:					
Unique method	4	3	5	1	0
In combination	1	6	5	2	3

[1] Sample size precludes firm conclusions concerning use of weapon information.

weapons, vehicles, interrogation of arrestees, and identification by victims (incorporated in the "other" category.[5] Modus operandi techniques and weapon information are used in only a few cases.

Table B-19 provides some information on the use of these methods to identify suspects in different types of crimes. The types of crimes selected include aggravated assault, burglary, robbery, petty theft, and auto theft. These categories demonstrated the most distinct correlations with followup methods used. The data in the table indicate the number of cases in which the method was used uniquely, or in combination with others.

Some conclusions we might tentatively draw from this table are as follows: First, there is a tendency to utilize combined methods, particularly where property, vehicles, or interrogation are involved. Care must be taken in interpreting these results, however, because of data collection ambiguities. For example, in the cases of auto theft, many of the "combinations" involved property and vehicle, but the "property" was actually the vehicle. The suspect was arrested because he had the stolen vehicle in his possession.

A second tentative conclusion concerns modus operandi data. These are most often used in combination with other methods, rather than uniquely. Because of the small sample, we should be careful not to conclude that the technique is confined to burglary. Robberies, on the other hand, tend to emphasize identification and interrogation methods because the robbery suspect has usually been seen by a victim or witness.

One problem in police work, which is obvious from the information on the unnamed suspect cases, is in the area of burglaries and thefts. Of 1,031 cases in this category, 937 were unnamed suspect cases. Of the 1,031, 626 were burglaries, 70 grand thefts, 311 petty thefts and 24 were multiple crimes where thefts were also involved. Arrests were made in 120 of these cases, 56 of which were of

[4] That result must, however, be interpreted carefully; some Los Angeles Police Department detective divisions require a followup report in all cases with property value over a designated amount.

[5] See annex 2, item 12.

named suspects. As we indicated earlier, half of the named suspect arrests were of individuals unknown to the victims or witnesses. The inevitable conclusion is that the major effective tool against the burglary-theft type of crime is the on-scene arrest, either following from a radio call or some field observation. Followup investigation appears to be very ineffective against this type of crime.

In looking for a ray of hope, we did uncover a situation with respect to fingerprints which merits further examination. Of the 626 burglaries, 307 have indications of evidence at the scene of the crime, in 269 of which a technical specialist was actually contacted to come out and view the evidence. When we speak of a technical specialist here we mean primarily, a fingerprint specialist.[6]

Unfortunately, the existing information in the files does not indicate how often the technical specialist actually visited the scene of the crime. We do know from police officers' comments that the shortage of technical specialist staff limits the number of cases in which they actually visit the scene. Of those 269 cases in which the technical specialist was contacted, 28 cases actually had fingerprint evidence booked. This represents almost 5 percent of all burglaries, or almost 10 percent of those in which evidence seemed to be available at the scene. This is a lower bound because, as indicated above, there are many cases in which the technical specialist does not actually visit the scene. It can be assumed that some percentage of those have fingerprints that could be used as evidence. Extrapolating this over the total number of burglaries in the city of Los Angeles, a minimum of 2,500 to 3,000 cases per year with fingerprint evidence can be anticipated.

One significant factor in solving crimes is vehicle information. Table B-20 summarizes the data on clearance of cases with good vehicle information. Of the 1,905 crimes, 231 had vehicle descriptions, 94 of which had license data. About 60 percent of these were unnamed suspect cases. Of the 94 total cases, 65 were cleared, 54 by arrests.

This section on investigative practices and problems has described some of the existing methods of clearing crimes. It has also exposed how little we know, in explicit terms, of the effectiveness of present methods. For example, for the purposes of optimum allocation of detective resources, it would be extremely valuable to have some quantitative estimates of the chances of clearing a particular type of case, given a followup investigation of a certain level of effort. This study did not attempt to explore that question; however, future research in the area should consider the design of an appropriate statistical experiment to develop information to assist police department commanders in allocating their investigative efforts.

ON-SCENE PATROL ARRESTS

An analysis of patrol arrests attests to the importance of the patrol function in dealing with crimes with unknown suspects. Of the 482 cleared cases, 127 were cleared due to an action initiated by some means other than radio call. As shown in table B-21, these 127 clearances included 116 arrests, 86 of which involved actual observations by an officer in the field. Only 5 of these were arrests at the suspect's residence.

Table B-22 lists the type of cases in the 116 nonradio call arrests. One of the most significant aspects of this table is the "other crime" category. This category includes a large number of narcotics offenses for which a specific category was not originally designated in data collection. Referring to table B-9, of the 112 cases in the "other" category, 76 were cleared. Thirty-nine of these resulted from nonradio call arrests. These represented almost 34 percent of all such arrests. Yet, the "other crime" category represents only 6 percent of all crimes. This result is primarily attributable to the high incidence of narcotics violations detected by field officers stopping vehicles for traffic violations or other suspicious activity.

The officer dealing with these field observation situations tends to rely considerably on the vehicle and warrant check. Table B-23 indicates the use of this information in those cases in which the officer is making a field observation. He is especially concerned with information about what suspects and vehicles are wanted.

Alarm data, although representing a small percentage of the cases, result in a reasonable probability of arrest by patrol officers. Twenty-eight crime cases in this sample had alarms involved, 19 of which were activated by the suspect, and 5 activated by the victim and 4 unidentified.[7] Of the 24 identified alarms, 7 arrests were made, all by patrol. However, where the suspect activated the alarm, only 4 out of 19 arrests were made; whereas where the victim activated the alarm, 3 out of 5 arrests were made.

Table B-20.—Use of Vehicle Information

Total crimes	1,905
Vehicle information present	231
License information present:	
Full	84
Partial	10
Total	94
For cases with license information:	
Named suspect cases	38
Unnamed suspect cases	56
Total arrests made	54
Other clearance	11
Total cleared	65

Table B-21.—Breakdown of Direct Observation Arrests

Total cleared cases—No radio call	127
Nonradio call arrests	116
Direct observations	93
No arrest	7
Arrests	86
By patrol	83
By detective	3
Breakdown of arrests:	
On scene	42
Vicinity	18
Residence	5
Other	16
Unclear	5
Total	86

[6] In the other 38 cases with evidence at the scene, evidence may have been present indicating method of entry, stolen property, and other items listed in annex 1.

[7] These were real alarms communicated to the dispatching center. False alarms were not collected here.

Table B-22.—Types of Crimes in Nonradio Call Arrests

	Number	Percent
Murder	1	0.9
Aggravated assault	11	9.5
Rape	3	2.6
Other sex	0	0
Burglary	17	14.7
Robbery	10	8.6
Grand theft	4	3.4
Petty theft	7	6.0
Grand theft—Auto	20	17.3
Simple assault	2	1.7
Worthless document	0	0
Malicious mischief	2	1.7
Other	39	33.6
Total	116	100.0

Table B-23.—Supplementary Information Used in Field Arrests

	Query results		Used Prior information
	Negative	Positive	
Vehicle license check	7	19	
Want/warrant check	42	14	
Wanted suspect [1]			194

[1] Includes the 14 positive warrant checks.

DISCUSSION OF RESULTS

The results of the foregoing analysis imply two very significant operational recommendations. The first regards preliminary investigation at the crime scene. We have noted that very little followup is undertaken by the detective force when there is little information about a given crime. Thus the theft and the burglary tend to be ignored by the detective unless there is something very specific for him to investigate. One problem in these cases concerns the patrol officer who, in making the crime report, is expected to make a preliminary investigation at the crime scene. Theoretically, he should make a check of the neighborhood to ascertain if any suspects or unfamiliar vehicles were observed in the vicinity. Unfortunately, due to lack of manpower and other pressures, preliminary investigation at the scene is extremely limited under present operational practices.

In discussing this requirement for increased preliminary investigation with command staff of police departments, it is not unusual to get the reaction that this investigative procedure is already in effect; in fact, the officers *are* trained to engage in such preliminary investigation. Nevertheless, the lack of patrol manpower prohibits the use of a field officer for that additional 30 to 40 minutes required at the scene of a crime, over and above the time spent in making the crime report. It is difficult to recommend additional patrol officers because there is already a problem in recruiting qualified patrol staff.

One possible solution to this shortage is to employ civilian personnel who are especially trained in investigative techniques but who do not require the operational training and physical capability of the field officer. This civilian investigative force could be called to the scene of a crime by the field officer after he has determined that no operational danger is involved.

The second operational recommendation concerns the present allocation of detective resources. In most departments the detective is used primarily as a followup investigator, and for many classes of crimes this is quite an appropriate set of activities. It is clear from our studies, however, that in the type of crimes in which the suspect is unknown, such as burglaries and thefts, the major success in dealing with these crimes is in the on-scene arrest. Followup investigation is rarely successful in burglaries and thefts; yet, because of the volume of these cases, detective resources are heavily allocated to such followup investigation. Detective forces should thus consider employing more field resources for dealing with that type of case.

This tactical detective force must not be saddled with the time-consuming, routine tasks required by followup investigation, such as processing prisoners, answering phone calls and making field investigation reports. We are *not* recommending here that we add more resources to the patrol force which would be responsive to calls for service; rather, we are stressing the use of a tactical squad with the specific responsibility of apprehending burglars and thieves in the vicinity of the crime being committed.

One final recommendation in the area of investigating crime: We have seen that in a significant number of burglaries, latent prints are left at the scene. In the present state of the fingerprint processing art, latent prints are more apt to be used in linking a specific suspect already known to the police, than as a means of finding possible suspects for the crime. Certainly the inability to search the entire fingerprint file on a single-finger basis definitely impedes the use of the fingerprint as an investigative device. The present clearance is less than 12 percent in these unknown suspect cases. Our study indicates that at the present time the existence of a latent fingerprint search capability might significantly improve the clearance rate in burglaries and thefts. Such a capability should be developed.

CONCLUSIONS AND RECOMMENDATIONS

This section reiterates some of the conclusions resulting from analysis of the Los Angeles Police Department data and expands on two particular recommendations for further research effort.

CONCLUSIONS

Response Time

The data collected on the response time in dispatching field units appears to support the hypothesis that faster response time leads to more arrests. The present manual method of dispatching for emergency calls still requires 1 to 2 minutes in the communications center, with an additional 3 to 5 minutes field response. The field response time is minimized if the closest available unit responds. More automated command and control systems can reduce the overall response time.

Criteria for Priority Call Assignments

The study of cleared and uncleared crimes related to radio calls indicates a possible area for improvements in crime prevention and case clearance. This would involve higher priority assignment for a selected number of suspect-on-scene or possible crime calls not presently given emergency status. A specific recommendation for research in this area is provided in the next section.

Improving Clearance of Cases with Unnamed Suspects

The data indicate that the clearance rate of cases with unnamed suspects is very low. Of 1,556 crimes in that category, only 181 were cleared. It was noted that few followups were made by detectives in these cases, primarily because of lack of information to initiate any investigation. Furthermore, most of the 181 clearances resulted from on-scene arrests stimulated by radio call or field officer observations.

Two conclusions about improving clearance of unnamed suspect cases follow. First, more preliminary investigation at the scene is required. Because patrol resources are scarce, a civilian preliminary investigative squad is recommended to serve this function.

Second, the reallocation of some followup investigators to a tactical force operating specifically against burglaries and thefts would seem to be desirable.

Latent Fingerprint Search Capability

In an estimated 2,500 burglaries per year in the city of Los Angeles, fingerprints are left at the scene. The prints are not now very useful for finding suspects, although they do serve a corroborative function where the suspect is known. A latent fingerprint search capability would provide solutions to some indeterminate proportion of these cases, depending on the availability of an adequately complete base of fingerprint records and the extent to which burglars take countermeasures, such as wearing gloves. If one were to attribute a value to solution of only $400, the average value of property taken, and if the police could solve half of these cases by fingerprint search, the benefits of solution would total $500,000 per year in the city of Los Angeles alone. Considering all the other metropolitan areas, adequate benefits should be derived to justify development of a latent print system.

RECOMMENDATIONS FOR FURTHER RESEARCH

Methods for Improving Police Effectiveness

The work described in this appendix could only begin to explore the characteristics of calls for service, crimes and arrests, and the patrol and investigative practices in dealing with these problems. The research was hampered by the fact that much of the needed information was not available in any accessible form. This is understandable, of course, since the information available in the police department is collected for current operational reasons, rather than to satisfy research objectives. Yet, such research on police operations is sorely needed.

Police practitioners generally operate on several operational hypotheses about what makes for effective policework. The researchers involved in this study have also developed some hypotheses based on a different orientation to policework. But few of these hypotheses can really be validated with the existing level of information available. Furthermore, many of the crucial operational issues are decided on intuitive grounds which may or may not reflect the actual situation.

What is needed, therefore, is a fundamental research and analysis program over a several year time period in one or more large metropolitan police departments. This program would attempt to explore in more detail the characteristics of crime, arrests, and field and investigative practices that were just explored in a preliminary manner in this study. Special data collection methods would have to be developed in order to obtain information on field practices without unduly influencing the practices by the fact that observations were being conducted. New methods of recording information specifically for the research studies would have to be employed and there would be some additional collection required on the part of a sample of patrol and detective officers.

This study would have to be of an iterative nature. It would begin with a series of hypotheses based on the results of this study, and for which data would be specifically collected. As analysis is undertaken, new hypotheses would be developed and would also have to be tested and special data collected for those purposes. It is clear that studies of this kind in various departments are essential if the police are to gain their factually supported understanding of ways to improve effectiveness.

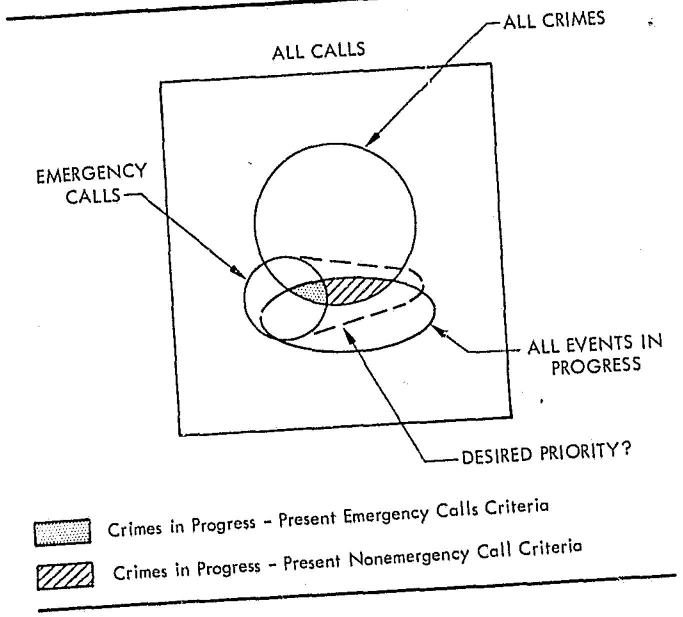
Criteria for Emergency Dispatching

One specific area of research uncovered by this present study is the need to reexamine criteria for priority dispatching. A specific program is recommended with two basic objectives: (a) To evaluate the present priority call assignments and criteria used in making them; and (b) to develop new criteria and test them under operational conditions.

The concept upon which this research is based is shown in figure B–4. All calls for service are represented by the overall square. Within that square is an oval-shaped area representing all crimes. Another smaller oval-shaped area represents events in progress at the time the call for service is made. This area overlaps with the crime area so that some of the crime calls are events in progress, but the majority of them are "take report" calls for crimes which have already occurred.

The present priority assignment for emergency calls is represented by the circle. Some noncrime events in progress are included, as well as some calls which are neither

FIGURE B-4. PRIORITY DISPATCHING CRITERIA



crimes nor events in progress. The "emergency calls" also include some crimes which have actually been completed at the time the call is received in the communications center.

Some events in progress are not actually considered potential crimes requiring rapid response at the time the call is received. This occurs for two reasons. In some cases, between the time the call is received and the officer's arrival at the scene, the situation has escalated to the point where a crime has occurred. In other cases, the information received by telephone is just not sufficient to make an accurate judgment. Obviously, if the communications center knew which calls fit into which categories in advance, it could make perfect priority assignment. The problem, of course, is that from the standpoint of the communications center, the situation in the field is not always clear.

At the present time there is a series of criteria which are used to assign priority to a call. The present study indicates that this priority may possibly be improved. To do this, we must evaluate the existing criteria in terms of actual cases. The steps required are:

(1) Determine the distinguishing characteristics of events in progress, as viewed from the communications center;

(2) Determine how many cases are actually events in progress;

(3) Evaluate what proportion of these escalate into crimes which would be preventable by rapid response;

(4) Evaluate what proportion are presently considered priority calls; and

(5) Determine the distinguishing characteristics of these escalatable events as seen from the communications center.

Having completed these steps, it would then be possible to develop and test new sets of criteria and see if they improve performance. A necessary requirement to accomplish this type of evaluation and testing is an audit of the present results of dispatching. This audit requires an evaluation of response time from receipt of a call to arrival at the scene, and a careful evaluation of the results of the field activity: Whether it involved preventive action, arrest or other clearance methods. Once the data collection techniques for such an audit are designed, they should be used to compare the present criteria and any new criteria that may be developed.

Specific tasks required for this research program include the following. It will first be necessary to monitor calls for service, preferably through recordings, to develop a taxonomy of characteristics which can be used for message content analysis. Patrol responses to calls would also be studied in a balanced sample in order to construct a similar taxonomy for those activities.

The next task would be to sample a new set of incoming calls and follow them through to activities in the field. For this, it would be necessary for the patrol officer to make careful recording of his receipt of call and arrival times. This could be simplified by the use of dictation equipment.

After this information is collected we would then be in a position to collate the communications characteristics with the field situations. The present priority call assignment criteria could then be analyzed and evaluated and the results of field activity evaluated as well. We would then be in a position to design a new set of dispatching criteria and test these criteria under operational conditions with the same methods used to test the present system. This would lead to an evaluation of the new criteria. At this point we would probably want to iterate on our design concepts and test once more before making the final recommendations.

ANNEX 1: CODING FORM FOR LOS ANGELES POLICE DEPARTMENT APPREHENSION STUDY

COMMUNICATIONS AND DAILY FIELD ACTIVITY REPORT DATA

		Column
DIVISION: -- / DAY OF MONTH (1-31) -- / SEQUENCE --		1-6
TYPE OF TICKET	(0) Blue/code 2 (1) Blue/code 3 (2) White (3) White/code 3	7
TYPE OF CALL	(0) Suspect on scene (1) Suspect just left (2) Take report (3) Possible crime	8
TIMES: ORIGINATED ------ : -----	DISPATCHED ------ : ------	9-13 14-18
UNIT ASSIGNMENTS	(0) Single time stamp (1) Multiple stamping (2) Code 1 (3) Quotes delay (4) Not available	19
DIFFERENT UNIT ASSIGNED	(0) No (1) Yes—by communication (2) Yes—unit request to handle	20
TIMES : FIRST RESPONSE ------ : ------	CLEARED ------ : ------	21-25 26-30
TYPE OF RESPONSE	(0) Code 4 (1) Code 6 (2) Request further information (3) Broadcast information (4) Other request (5) Clear	31
CRIME REPORTED	(0) No (1) Yes—radio call (2) Yes—other	32
TIMING OF ARRIVAL	(0) Suspect on scene (1) Suspect GOA (2) Take report only	33
DR#		
RESPONSE TO CITIZEN	(0) No (1) Not shown (2) Victim (3) Witness	34
OBSERVED BY UNIT	(0) No (1) Not shown (2) From vehicle (3) Out of vehicle (4) On foot	35
WHAT OBSERVED	(0) Crime (1) Suspect (2) Vehicle	36
LICENSE CHECK	(0) No (1) Not shown (2) Yes—Negative (3) Yes—Positive	37
WARRANT/WANT CHECK	(0) No (1) Not shown (2) Yes—Negative (3) Yes—Positive	38
WANTED SUSPECT	(0) No (1) Not shown (2) Current crime (3) Previous crime	39
WANTED VEHICLE	(0) No (1) Not shown (2) Yes—license (3) Yes—identifiers (4) Yes—both	40
TIMES FROM DAILY FIELD ACTIVITY REPORT: BEGIN -----:------	END ------------	41-45 46-50

CRIME, FOLLOW-UP REPORT, ARREST DATA

DATE AND TIME OF PRIOR CRIME:

		Column
ARREST MADE	(0) No (1) By patrol (2) By detective (3) Not shown	51
CHARGE	(0) This DR (1) Other DR this series (2) Other charge	52
WHERE	(0) On scene (1) Vicinity (current) (2) Residence (3) Other (4) Unclear	53
DATE OF ARREST	---------- Month ------ Day ------ Year	54-59
TIME OF ARREST	------: ------	60-64
PRIOR INFORMATION	(0) No (1) Not shown (2) Specific premises (3) General area	65
SOURCE OF INFORMATION	(0) Not shown (1) Department briefings (2) Communications (3) Informer	66
TYPE OF CRIME	| ------ | ------ | ------ (0) Murder (1) Aggravated assault (2) Rape (3) Other sex offense (4) Burglary (5) Robbery (6) Grand theft (7) Petty theft (8) GTA (9) Simple assault (10) Worthless document (11) Malicious mischief (12) Other	67-72
FORCE OF FEAR INVOLVED	(0) No (1) Yes	73
VICTIM ASSAULTED PHYSICALLY	(0) No (1) Yes—uninjured (2) Injured (3) Fatal	74
SUSPECT WEAPON INVOLVED	(0) No (1) Yes—unseen (2) Yes—seen	75
TYPE OF WEAPON	(0) Hand gun (1) Other gun (2) Knife (3) Other sharp instrument (4) Blunt instrument (5) Other	76
PHYSICAL FORCE INVOLVED	(0) No (1) Yes	77
SPECIFIC THREAT INVOLVED	(0) No (1) Yes—victim (2) Victim's family (3) Other	78

	Keypunch Ident Number +9	Column 1-7
ATTEMPT TO TAKE PROPERTY	(0) No (1) Successful (2) Unsuccessful	8
DOLLAR VALUE REPORTED	(6 figures to nearest dollar)	9-14
TRANSPORTABLE	(0) On person (1) Carry (2) Support needed	15
CHARACTER OF ITEM	(0) Negotiable (1) Fenceable (2) Possible personal use	16
CRIME INSIDE BUILDING	(0) No (1) Yes	17
TYPE OF BUILDING	(0) Residence (1) Nonresidence	18
TYPE OF RESIDENCE	(0) Single family (1) Apartment (2) Hotel-motel (3) Garage or shed	19
TYPE OF NONRESIDENCE	(0) Market (1) Liquor store (2) Other retail (3) Service station (4) Financial institution (5) Business office (6) Nonretail commercial (7) Hotel-motel (8) Bar-cafe (9) Other	20
ACCESS TO CRIME SCENE	(0) Building secure (1) Open access area (2) Open building, secure room (3) Open access to room	21
ENTRY METHOD IF ILLEGAL	(0) Force (1) Uninvited (2) Subterfuge (3) Key	22
OCCUPIED AT TIME OF CRIME	(0) No (1) Yes—aware of crime (2) Yes—unaware	23
PREMISES ALARMED	(0) No (1) Not shown (2) Audible (3) Silent	24
HOW ACTIVATED	(0) By occupant (1) By suspect (2) Deactivated by suspect (3) Not activated	25
HOW SERVICED	(0) By company (1) By police (2) By victim	26
CRIME IN STREET	(0) No (1) Public street (2) Alley (3) Private grounds (4) Publicly accessible area (5) Other	27
CRIME IN VEHICLE	(0) No (1) Yes	28
TYPE OF VEHICLE	(0) Suspect's (1) Commercial (2) Common carrier (3) Victim—personal	29
ATTEMPT TO SEXUALLY ASSAULT VICTIM	(0) No (1) Yes—unsuccessful (2) Successful (3) Possible intent	30
PRIOR RELATIONSHIP WITH SUSPECT	(0) No (1) Yes	31
INITIAL CONTACT WITH VICTIM'S CONSENT	(0) No (1) Yes	32
ACT WITH VICTIM'S CONSENT	(0) No (1) Age under 14 (2) Age 14 to 18	33

		Column
VICTIM CAPABLE OF CONSENT	(0) No—unconscious (1) No—but conscious (2) Yes	34
ABERRANT SEX ACT	(0) No (1) Yes	35
OTHER SEXUAL OFFENSE	(0) No (1) 288 (2) 288A (3) 311 (4) 647 (5) Other	36
SUSPECT SEEN	(0) No (1) By victim (2) By witness (3) Both	37
SUSPECT NAMED	(0) No (1) Yes—unconfirmed (2) Yes—confirmed (3) Partial or nickname	38
SUSPECT DESCRIBED	(0) No (1) Yes	39
SEX	(0) No (1) Yes	40
RACE	(0) No (1) Yes	41
AGE	(0) No (1) Yes	42
HEIGHT	(0) No (1) Yes	43
WEIGHT	(0) No (1) Yes	44
HAIR	(0) No (1) Yes	45
EYES	(0) No (1) Yes	46
COMPLEXION	(0) No (1) Yes	47
CLOTHING	(0) No (1) Yes	48
MANNER OF SPEECH	(0) No (1) Yes	49
MARKS/SCARS	(0) No (1) Yes	50
OTHER IDENTIFIERS	(0) No (1) Yes	51
PHYSICAL EVIDENCE REPORTED	(0) No (1) Yes—none booked (2) Yes—booked	52
TECHNICAL SPECIALIST CONTACTED	(0) No (1) Yes	53
PRINTS AT SCENE	(0) No (1) Yes	54
EVIDENCE OF ENTRY	(0) No (1) Yes	55
EVIDENCE OF WEAPONS	(0) No (1) Yes—ballistics (2) Yes—no ballistics	56
EVIDENCE OF STOLEN PROPERTY	(0) No (1) Yes	57
OTHER EVIDENCE	(0) No (1) Yes	58
VEHICLE USED BY SUSPECT (not solely GTA)	(0) No (1) Yes (2) Victim's vehicle	59
VEHICLE SEEN	(0) No (1) Yes	60

		Column
LICENSE	(0) No (1) Yes (2) Partial	61
MAKE	(0) No (1) Yes	62
MODEL	(0) No (1) Yes	63
YEAR	(0) No (1) Yes	64
COLOR	(0) No (1) Yes	65
SPECIAL IDENTIFIERS	(0) No (1) Yes	66
FOLLOWUP REPORT MADE	(0) No (1) Yes	67
SUSPECT NAMED IN FOLLOWUP INVESTIGATION	(0) No (1) Yes (2) Yes—method not shown (3) Yes—different from C.R.	68
BY PHOTO IDENTIFICATION	(0) No (1) Yes	69
MODUS OPERANDI	(0) No (1) Yes	70

		Column
STOLEN PROPERTY	(0) No (1) Yes	71
WEAPON	(0) No (1) Yes	72
VEHICLE	(0) No (1) Yes	73
INTERROGATION OF ARRESTEE	(0) No (1) Yes	74
OTHER	(0) No (1) Yes	75
CLEARED BY ARREST	(0) No (1) Yes—filing (2) Yes—other	76
OTHER CLEARANCE	(0) No (1) Juvenile (2) Prosecutor chooses not to file (3) Victim refuses (4) No crime (5) Other	77
NUMBER OF SUSPECTS ARRESTED		78
NUMBER OF DR'S CLEARED		79-80

ANNEX 2: DEFINITIONS, MEANINGS, AND CATEGORIZATIONS

1. If no actual arrest was made, the case was not coded as cleared by arrest, even if the investigator's followup listed the case as cleared by arrest. In those cases, the "other clearance" box was checked by our data collectors. This was especially important in cases where a warrant was issued but the arrest had not been actually consummated at the time of our study.

2. Some followups were found in the file which did not indicate any actual investigative action by the detective, but merely reported supplemental information provided by the victim; e.g., adding a serial number for a stolen television, or providing a list of additional property stolen and its value. In those cases the officers were instructed to ignore that followup report, thus limiting the followup report category to actual investigative action taken.

3. It was established that the department's policy was automatically to file for a complaint whenever a misdemeanor arrest was made. Hence, a misdemeanor arrest always resulted in a "yes-filing" category in the cleared-by-arrest item.

4. Where no arrest was made, no case was actually counted as cleared in the "No. of DR's cleared" item, even though there may have been some other method of clearance. Discrepancies in counting can be better accommodated by keeping the "other clearances" separate from the arrests.

5. In theft from automobile the dollar value of the property was often missing in the crime report. We established the policy that the coding officer would estimate that value.

6. Grand theft—Auto was not coded as a crime in vehicle nor a crime in the street. It was coded as an attempt to take property; however, the dollar value was omitted. Burglary or theft from an automobile was coded as crime in vehicle.

7. Even in cases where no crime was reported, the officers attempted to fill in the category "timing of arrival," indicating whether, when the field officer arrived, the suspect was on the scene, etc.

8. Worthless document or fraud were not coded as attempts to take property. However, some errors in coding this category are expected.

9. It was noted that grand theft in California is usually of property with value greater than $200. Some cases, however, may involve less than that amount, particularly if guns, citrus fruit, or certain animals are stolen.

10. In considering the source of prior information, the category "informer" was used to designate a witness as well as a specific informer for the police department.

11. If a suspect was named in the crime report but was not named in the followup, the implication is that there was no evidence to connect that suspect to the crime.

12. In examining the method of naming the suspect in the followup investigation, provision was made for photo identification as a specific category. However, identification through observation by victim or witness was coded as "other" because of the lack of an appropriate category.

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FINGERPRINT CLASSIFICATION

by Thomas C. Bartee

Contents

THE PROBLEMS

The uniqueness of fingerprints as a method of identification has led to their widespread use and to large collections of fingerprints being stored at city, State, and national levels. This considerable use of fingerprints for identification has led to several problems in maintaining and searching the large files. Also, the present systems have a basic limitation of not being able to locate a suspect on the basis of fingerprints left at a crime from any but a small subset of the total prints now on record.

As an example of the magnitude of the present problem, let us consider the largest single collection of fingerprints now in existence, which is maintained by the FBI in Washington, D.C. The FBI files now contain about 16 million sets of different criminal prints plus about 62 million different Civil Service and Armed Forces prints. Many persons have several sets of fingerprints in these files so that the total number of fingerprint cards now in the files exceeds 179 million. Each day the FBI receives about 30,000 sets of fingerprints to be processed, of which approximately 10,000 sets are based on arrest. Most of the remaining prints relate to national security, being used for identification of Government employees and for checking to see if persons who will be employed in security positions have arrest records. The FBI employs about 1,100 personnel to process these daily demands for identification, add new prints to the file and delete old prints.

Given a set of fingerprints which are to be searched against the criminal file to see if the person owning the prints has a prior criminal record, some system is needed whereby the total number of cards to be examined by visual inspection can be limited to relatively few. This is the problem of fingerprint classification. The system which has been and is most used was basically set down by Sir Edward Richard Henry in about 1903. This system has been subsequently modified to meet particular demands but remains the fundamental technique for fingerprint classification.

The Henry system is that primarily used by the FBI. New York State, for instance, uses what is called the American system [1] which differs only in detail from the Henry system. In any fingerprint system, whether manual, semiautomatic, or automatic, the classification system is of primary importance, for it is the classification system which determines the extent and the efficiency of the search process.

The most significant aspect of the present search procedures lies in the fact that one must have 10 ordered fingerprints in order to use the present classification system. This is to say that in order to enter the files, using the classification formula now in use, one must have a full set of 10 fingers. An immediate drawback to this system can be readily seen. When fingerprints are inadvertently left by a criminal at a crime, only one or perhaps several prints may be available to law enforcement officers. Using the present system, there is, therefore, no means of directly entering the files to search for prints of this type. In order to get around this problem, some city, State, and Federal agencies have, in addition to their large files, small files called "latent files" classifed so that it is possible to search them on a finger-by-finger basis. The mechanics of this search are of course different from that of the 10-finger search and the actual categorization of latent prints depends a great deal upon the ability of certain fingerprint experts both to work with and extrapolate data from the latent prints (which are liable to be quite poor) and to manipulate the latent print files. As a result, latent print files tend to be very small, generally containing only a few thousand prints. For both Federal and State agencies, the latent print files will contain only the fingerprints of criminals who are particularly likely to be involved in certain kinds of crimes, and

[1] "American System of Fingerprint Classification." New York State Department of Correction, Division of Identification, Albany, N.Y., 1963.

prints are added to these files as a result of experience on the part of the law enforcement officers involved.

It should be noted that very little statistical data of substance concerning the use of latent prints appears to be presently available.[2] As a result, latent prints are not widely used in attempting to identify criminals and are more widely used to confirm identification or to eliminate suspects. In each of these cases, the comparison can be made directly from the prints of suspects rather than by searching a file.

Probably the most significant contribution which could be made in the fingerprinting science would be that of giving to law enforcement agencies the ability to search fingerprint files for latent prints. It is difficult to estimate the magnitude of this contribution for we have no statistics on what the yield would be in terms of total number of crimes solved each year nor in terms of the amount of effort on the part of law enforcement agencies which would be saved due to use of fingerprint information for identification rather than other techniques. One difficulty in making such an estimate is the fact that law enforcement agencies are aware of the deficiencies of the present system, and as a result rarely attempt to make identification by means of latent prints. As an estimate of complexity of this problem, let us note that the latent print files only range from about 1,000 to 30,000 individuals for the larger identification agencies while their main fingerprint files generally number in the millions.

Secondary advantages primarily would involve more efficient processing of fingerprint cards in terms of economics and total number of people involved. Also, if fingerprint files were automated in an adequate manner, it might be possible to expand the size of the files which are maintained and searched.

Some explanation of the latter statement is perhaps in order. Let us again use the FBI files as an example. When a defense agency or a government contractor sends a fingerprint card to the FBI for security clearance, the prints on this card are searched against the arrest file. If the person involved has not committed a criminal offense, this is recorded and the fingerprint card is returned to the submitting agency. Fingerprint cards from defense contractors are not maintained in the FBI file, but are simply processed and returned to the contributing agency. This is done in order to keep the files to a reasonable size.

It is clear that in order to handle latent prints, a different classification system must be used for entering the files. However, because of the magnitude of the search procedure, regardless of the classification technique used, it appears that some degree of automatic search would be necessary. This means that to handle latent fingerprints with large files, it will be necessary to use digital data processing equipment at least to aid in the search. The question then arises as to the degree of automaticity which should be implemented.

There are several levels at which computer systems might be used in automating the present fingerprint files for both State and Federal agencies. Several of these are:

(1) *Completely Automatic Systems.*—These are systems which would scan fingerprint cards automatically, classify them using a general purpose digital computer, search a file of prints, locating and finally correlating a card in the file being searched with the incoming fingerprints. Such a system would automatically process cards without human intervention.

(2) *Semiautomatic System.*—The process of pattern recognition and classification using electronic scanners could be supplemented by human intervention, that is, by using trained technicians to scan the prints either in their present form or by means of some pictorial display, classify the gross patterns, locate such critical points as the core and delta of a print, and identify such minutiae as islands, short ridges, bifurcations, and other fingerprint details which are useful in classifying particular prints. The system might be automatic from that point or might ask for further participation by an operator in case the computer located a number of cards and was not able uniquely to select the proper match from among these cards. Trained technicians could then scan the cards selected by the computer.

(3) *Computer-Aided Search.*—This type of system is the only one which has been used to date. Humans perform the entire classification process and also enter any pertinent facts, such as age or sex, on the cards. The computer is used to facilitate the search of the files for cards of specified classification and to deliver candidate cards to the operator for manual search. The primary function of the computer is bookkeeping, which it accomplishes by making records neater and simpler, by shortening and making more efficient the process of searching the files. Fingerprint experts are needed for both the classification and final comparisons.

The relative success of any of these systems is contingent upon the efficacy of the classification system. In order to automate a system satisfactorily, one must not only know the general details of what must be done, but the algorithms which are used for searching and classifying must be well defined before the system can be satisfactorily put into operation. It is therefore necessary to investigate further the present classification system both with a viewpoint toward implementation for the 10-finger system and with a viewpoint toward extending the ability to recover latent prints.

Since several books have been written describing the present classification system and details have been published in several reports, it will be our purpose here only to comment briefly upon the use of the Henry system with its modifications in locating prints in the 10-finger file and on the use of a system of this type in attempting to locate latent prints in a large file.

In short, the present day systems use information concerning left or right hand, finger positions, basic fingerprint patterns such as loop, whorl, and arch, and finally, ridge count or whorl tracing. The classification formula which is used to locate fingerprints falling in a particular category is derived from codification of this information into alphanumeric form. In order to facilitate the filing and search process, the formula is segmented into primary, secondary, subsecondary, final, and extension parts, but these are subservient to the principal formula. Additional information such as sex and age is sometimes used to narrow the search. Despite the work that has been done, the large number of prints on file causes this system to locate not specific cards, but rather large sets of cards in the file.

As an example of the problems which one finds when a specific classification system is used to implement a search, about 65 percent of all fingerprints are loops and about 60 percent of all fingerprints are ulnar loops, so that when the first step in the Henry procedure is followed, we find that in the single classification of 10 ulnar loops on both hands, approximately 800,000 of the 16 million arrest prints now on file fall into one category and this comprises 5 percent of the total file. This should make it evident that knowledge of the statistics of fingerprint patterns is necessary in addition to general knowledge concerning the patterns in order for a filing system to be efficient, and strongly indicates that statistical studies of any improved classification system must be made before such a system could be safely implemented.

Concerning latent prints, the problem of narrowing down the search becomes far more difficult, for less data is presented to the system user and a great deal of redundant data must be contained in the file in order to limit the search sufficiently for sets of latent prints which contain perhaps one or two fingers. As an example of the severity of this problem, a New York State Identification and Intelligence System Report[3] indicates that, given two fingerprints both on the right hand, one of which is from the index finger and is an ulnar loop with a ridge count of nine, and the other from the right middle finger with an ulnar loop with a ridge count of 12, a list of 1 million cards would produce 45,000 candidate prints based on this information alone. Further, if only the right middle finger were obtained, 370,000 prints would be selected from a file of 1 million.

In order, therefore, to implement a latent print search procedure, we must have information in addition to that which is commonly used in the Henry system. Fortunately, such information is available in prints, consisting of what are called the minutiae: The bifurcations, islands, ridge endings, divergences, and the positions and orientations of such ridge features in relation to each other. Such a categorization would depend upon the establishment of a coordinate system probably based upon the core and delta of each fingerprint. The possibility of implementing a large file using data of this sort seems quite hopeful and it is recommended that studies in this area be undertaken at this time. The following sections give a more detailed plan of attack.

RECOMMENDATIONS

Our major recommendation is that research should be sponsored into the use of electronic data processing equipment to process fingerprint data. A study should be initiated immediately on classification techniques. This study should gather information on the statistical distribution of fingerprints according to the various criteria now being considered. The study should investigate the distributions within categories (for instance, the variations in ridge counts from core to delta for ulnar loops). Ultimately, a search procedure should be established based on the data gathered. Correlation techniques for searching the files should also be investigated.

Particular experimental work should support the theoretical studies. For instance, since actual statistics will be required on fingerprint characteristics in order to evaluate classification techniques, a small model of an actual system should be put in operation in order to obtain the necessary data. These data would also provide operating statistics which would aid in the design of the system.

With the cooperation of law enforcement agencies, the gains to be accrued from an ability to efficiently search large files of fingerprints should be assessed. From the data collected, estimates should be developed of such factors as the number of additional criminals that might be apprehended if latent prints were used, savings in police effort which would result, benefits of a nonautomatic 10-finger system, etc.

The studies should be coordinated with State and Federal agencies. Several State agencies have initiated work in this area, the FBI has collected some proposals, and several companies have invested modest amounts of money in research efforts. The present level of support is almost certainly below a critical threshold, so additional Government support should be committed. The problem of State and Federal support and the role of local and Federal agencies also needs to be reconciled.

DISCUSSION OF RECOMMENDATIONS

Our major recommendation indicates that computer technology can alleviate the present fingerprint processing problem. There are a few characteristics of the proposed system which bear examination at this point. It appears that an initial system must be semiautomatic. The problem of reading from fingerprint cards or films using present day techniques and then categorizing the fingerprints completely automatically probably exceeds the capability of our present technology. Pattern recognition has been a difficult field and the type of pattern recognition called for in processing fingerprint data is particularly difficult. While the computer may be of significant assistance in locating points, making measurements, or facilitating the assigning of descriptors to prints, it does not appear feasible at this time to make the system completely automatic.[4]

A semiautomatic system has a great many advantages. There are no immediate problems in implementing such

[2] New York City has been doing some interesting work on fingerprints including the use of a substantial latent print file. Their data indicate an 8 percent yield on workable prints, which seems remarkably high compared to other reports.

[3] Kingston, C. R., P. D. McCann, C. E. Robinson, D. D. Rudie. "NYSIIS Fingerprint Classification and Identification System." Status Report, October 1965.

[4] The United Kingdom now uses a computer to facilitate their fingerprint filing operations, but their delegate at an Interpol Conference stated it did not appear possible at present to operate without operator intervention. Also, the other delegates agreed that the major problem at present lay in the coding or classification, whether one considered 10 fingers or latent searches.

a system and it is clear that such a system will work at least as well as present systems.

Our belief is that the system should not only be semiautomatic in that operators at consoles are presented with fingerprint data which they then classify, but also that there be some interaction between the computer and the operator, so the computer can call for additional information when it is needed to facilitate the search process. The reason for this is that the additional information which is called for in order to locate the given set of prints in the file varies according to the characteristics of the print or prints being examined. If the initial data inserted into the informal retrieval system is sufficient to partition the data bank into a very small set of cards, then very little and simple additional information will be required to make a unique identification of a set of prints. If, however, the initial data presented results in a partition of the file such that the number of cards to be examined is quite large, not only will more specific information need to be inserted to give a unique identification, but also the type of information which is needed may be different from that in the preceding case. By allowing this interaction between operator and computer both the efficiency and the efficacy of the system should be significantly improved.

The semiautomatic system would be particularly appropriate for the processing of latent prints because of the need for an operator to extract meaningful data from smudged or incomplete prints.

With regard to the computer itself, there have been various estimates as to the computational power necessary. However, if the system is semiautomatic and the computer is not called upon to do pattern recognition of the prints, the computing load appears to be quite modest from a speed viewpoint, and an intermediate size digital computer can be used without difficulty. On the other hand, a large number of external storage devices are required to store the actual data. Fortunately, the price of external storage is low and becoming lower almost daily, and such bulk storage devices as magnetic tape, SCRAM, data cells, and many other devices will provide adequate storage at a quite modest price.

In addition to this, there is the problem of storing the actual prints and records of the system, and this seems best accomplished by means of photographic film, which is an efficient way to store high information content data. Again, the price is quite modest and by using film records of this sort the total volume of the stored data will be significantly reduced. For example the FBI file, which now requires a multistory building, could be reduced to perhaps two rooms for the data processing complex.

Display devices do not appear to be any particular problem at the present. We ask only that the prints be displayed for an operator who then introduces classification data into the system by identifying points using a light pen, a keyboard, or some other manual means. Entering of data can be supplemented by the computer and console working together. For instance, the distance from core to delta or the number of ridges from core to delta can be easily calculated by a console plus computer, once the core and delta have been indicated by an operator. This leaves the operator free to make the more difficult decisions such as identification of particular patterns (whorl, loop, arch, etc., and associated left and right slant characteristics).

The above details outline the general form of a system. We have an operator at a console using the basic Henry characteristic data on individual fingers for initial information to the computer (that is, the operator identifies whether or not each of the fingers is a loop or whorl, has a left or right slant, etc.). Following this the computer makes several simple measurements corresponding to those now made in ridge counting and enters these data into the file. Now, if the computer needs information, it requests it of the operator.

Following the supplying of the additional data by the operator, the computer then locates a card or set of cards, which are displayed to the operator for further processing. (The computer would not be restricted to only one request. Several passes might be made when necessary before cards are actually delivered for final verification.)

How far the search process should take the system is a point which must be considered at this time. It is our view that in most cases when finger information is available the system should deliver a particular card to the operator of the system as the result of a search. In some cases it would certainly be acceptable to deliver several cards to the operator, though the occurrence of this should be kept to a minimum, and perhaps 10 cards on rare occasions seems a reasonable upper bound.

The maximum number of cards that might be delivered to an operator is obviously related to the amount of information (number of descriptors) delegated to each print by the classification system, the number of search passes, etc. The economics of the system design requires a balancing of more thorough computer searching against the cost of operator intervention, for example.

There are several more subtle points. Since no system, including the present, will be perfect, particularly when latent prints are considered, we must consider the implications of missed identifications versus delivery of too many cards or erroneous cards. A comparison with present manual systems would be useful at this point, and it might be profitable to study existing systems to derive statistics of this operation. Several such tests have been initiated in New York State.

For latent prints the situation is of course more complicated, and the number of cards delivered must obviously vary considerably with the quality of the latent prints offered to the system. It is quite conceivable that individual cards might be delivered by the computer as a result of a single latent print, but it is also likely that a hundred cards might be the result of a search. In some cases where prints are particularly bad, a thousand or more cards could be delivered. We would hope, however, that these cases would be comparatively rare. If a final choice is to be made as the result of the computer having delivered several cards, the operator makes this by means of his display, examining the prints from the offered cards and finally selecting a particular print if possible, or otherwise indicating that the search of the files has resulted in no satisfactory match.

The system should be so designed that it can handle both 10-print or latent-print information. Thus the coding will not be in the customary Henry alphanumeric system, but rather on a finger-by-finger basis using individual plus collective prints to refine the file system in cases where all 10 prints are available.

The first step in the proposed research program consists of determining a classification system by means of which individual prints can be located in a master file containing perhaps over a hundred million total individual fingerprints. The study should concern itself not only with the location of sets of prints using 10-print data as input, but also the latent print problem, thereby introducing a need for additional storage because of the additional information needed to locate individual prints. Also, since latent prints are quite often of bad quality and many of the minutiae may not be present, it would be necessary to add redundant information even beyond that needed to locate clean and complete single prints.

After the classification system has been decided upon, the total volume of storage will be known, the size of the data bank can be calculated, and equipment costs can be determined by inquiries directed to a number of manufacturers. At that time, decisions concerning access time versus price and the partitioning of the filing pieces can be made. At that time also, one will be able to determine the class of computers which are capable of handling the present processing load, the numbers of calculations which the machine must make during both average and peak periods, and the amount of peripheral equipment which will be required.

With regard to the console, the classification system will doubtless prejudice the selection of consoles, although several commercially available consoles appear reasonable at this time. Some work might also be done on developing better means for taking fingerprints and better or perhaps even more exotic future techniques for extracting the fingerprint information. The means for storing the actual prints in the system on photographic film can also be established by presenting the system requirements to manufacturers of photographic information retrieval systems. This will specify the system and the anticipated cost of developing, purchasing, and operating such a system. It is felt that these will be quite modest with respect to the present operating costs for large systems. Following this phase of the study, the decision can be made to begin construction of an automatic fingerprint processing system.

THE FINGERPRINT CLASSIFICATION TECHNIQUES STUDY

Let us return once more to the problem of classification in a large file of fingerprints. Quite a number of different proposals have been made as to possible techniques for subdividing the fingerprints in a file. For instance, recent industry proposals suggest that by means of a Fourier series, or by considering fingerprint data as vector fields associated with Laplace equations, parameters can be mathematically generated which may make it possible to classify the fingerprint data in a system. In contrast to this, the present system, after using the fundamental Henry characteristics, relies on the minutiae of islands, ridge endings and bifurcations. The location of these is used by fingerprint experts in court proceedings as well as for locating prints in the file. It is our opinion that locating these minutiae will enable the classification procedure to advance beyond the initial stages. It appears in most reports, however, that it is not the general contour in a print which makes the print identifiable, but the existence of irregularities in the flow lines or ridges. For this reason, it is recommended that the proposed systems using minutiae to characterize and categorize fingerprint data be studied in some detail using actual prints for data. In addition to locating the minutiae in the print, which is straightforward for an operator and not too difficult for a computer, it is necessary either to establish a coordinate system in order to refer the location of these minutiae to other prints, or to use relative information which associates one ridge ending or bifurcation with another. In addition, there is angular information associated with each of these singular points which may also be used as descriptive data but this appears to lack the variance necessary to make this information really useful for further refining the partitions of the file.

Unfortunately, it is difficult to say at this time exactly which of the proposed schemes will work best in the sorting of fingerprint data. In order to make an effective system, it is therefore necessary to study a set of actual cards using a simulated semiautomatic system and to attempt identification of both 10-print cards and latent prints using such a system. The proposed study would use a simulated classification system which would resemble in actual operating practice the proposed systems, utilizing several consoles with operators and a number of fingerprint cards from one of the present files. By repeatedly attempting to locate cards in the file using fingerprint data and by a systematic study of the characteristics of the prints which are on file, it will be possible to determine which of the proposed classification systems will work best.

Classification is the step in the automatic retrieval process which contains major unknowns at the present. There is certainly no problem in the information retrieval part of the system, given an adequate classification system, nor is there a problem in sorting the necessary volume of data nor in providing the computer speeds necessary to retrieve cards efficiently given adequate input data.

It seems clear that a study of the classification problem will prove useful only if it deals with actual fingerprint cards and fingerprints in existing files. Theoretical studies would be restricted to work with statistical distributions and these are not presently available. The cost of such a study would be perhaps $500,000 to $1 million. Several consoles which are commercially available can be purchased in the immediate future. Study contracts can be let and, given the cooperation of a major law enforcement agency, it would be possible to initiate such a study in the very near future. This seems the necessary first step to any implementation of a computerized fingerprint retrieval system. It would, in addition, give us considerable information on the subject of locating latent prints in files which are now in existence, and should be helpful to all law enforcement agencies in coping with their problems associated with latent prints. It would also supply statistical information concerning the anticipated consequences of enlarging the present files.

Further steps would, of course, be based on the results of the first study. There appears, however, to be no basic reason why a classification system cannot be implemented. The problem is simply that sufficient knowledge is not now available. The study would, of course, provide more knowledge than this, for simulating certain parts of the proposed system will give accurate information on operational speeds and efficiency which will be useful in any future system.

POLICE MOBILE RADIO COMMUNICATIONS SYSTEMS
by Peter M. Kelly

Contents

INTRODUCTION

POLICE RADIO OPERATIONS

Large police mobile radio networks are characteristically organized in a centralized geometry with the two-way communications channels radiating outward from the dispatching center to the mobile units in the field as the spokes of a wheel radiate out from the hub. This network geometry is convenient for the normal mode of police operations, but less well adapted to the emergency mode.

The *normal mode* of operation of a police mobile radio network is built around the individual mobile police vehicle and its occupants as the fundamental guardians of law and order. The mobile units patrol well defined "beats," receiving assignments from the dispatching center, and monitor the activities of mobile units on adjacent beats, moving to be in a position to render aid in pursuit if needed.

The *emergency mode* of operation of the police mobile radio network must provide for the organization of police mobile units into tactical operation units for dealing with large scale riots, disasters, or demonstrations. The network topography is no longer a simple wheelspoke since control of the tactical force may be given to a command vehicle on location in the emergency area. This latter mode of operation is one for which police departments generally have not been prepared in the past. In recent years, however, the forward looking departments have been making substantial changes both in organizational procedures and in design of their communications networks to be able to shift into this mode of operation as required.

In a number of the larger, single-agency, police networks, the geometry just described can be recognized particularly if future plans as well as present status are taken into account. Over major population areas, however, because of the multiplicity of municipal, county, and State agencies involved, a large number of individual networks are found to exist, all overlapping each other in their radio coverage. In taking areawide overviews, it is difficult to identify any discernible pattern. In addition, the existing police radio networks are plagued with a number of severe shortcomings. The most serious of these shortcomings is the severe crowding of the police radio bands.

The overall shortcomings of present police radio communications have a number of clearly defined characteristics:

> The congestion of the police radio channels is most severe in the areas around the major population centers. In these areas, there are too many police radio users and too few radio channels allocated for police use.
>
> In these major population areas, as in all areas of the country, police radio is characteristically organized into a large number of small, independent networks which are ineffective in terms of interagency communications and coordination and inefficient in use of the limited available radio spectrum. Each little municipality will often have its own small, independent police network.
>
> Even in those areas where large police networks exist as in major cities or countywide systems, there is virtually no use made of the methods of modern communications technology to even the channel loading or relieve the congestion at times of heavy traffic.
>
> New devices required for improved police operation such as automatic car locators, small personal radios for use away from the car, and teletype in the car can be expected to create requirements for additional radio spectrum space for police use.

The spectrum congestion evidences itself not in an actual breakdown in police communications. The dispatchers' messages to the cars are sufficiently imperative that police make certain that these messages get through even in the most adverse circumstances. The spectrum congestion evidences itself more nearly in a gradual deterioration of police capability which becomes dramatically evident when communications are badly needed and not available, as during riots or other emergencies.

Finally, the money allocated in the police budget for equipment as opposed to money for personnel is characteristically extremely small. The Los Angeles Police Department is completely mobile, yet 93 percent of its budget is for personnel. A more dramatic example of the small proportion of total police funds used for equipment is provided by comparing equipment and personnel costs for conducting police mobile patrol. For a two-man police radio car on 24-hour duty, three shifts of two men each are required, plus two additional shifts for relief—sick time, days off, other duty, vacation, etc. Hence, 10 men are needed per vehicle at approximately $10,000 per year. (These figures are halved for the one-man car.)

The equipment costs are $2,000 for the car, $700 for radio equipment, and $100 for the shotgun and other equipment, totaling $2,800.[1] These equipment costs are amortized over a 3- to 5-year period. Thus, using 3 years as a conservative estimate, the annual equipment costs (not including maintenance), total $930 for the car and its associated equipment. This is only 1.8 percent of the total costs for a one-man car and 0.9 percent for a two-man car.

The desired capability for police radio networks encompasses operation in the normal mode as described above the majority of the time, in the emergency mode when required, and in a number of additional modes thus far not available to them or available only to a limited degree. These modes include:

Car-to-Car Capability: The police are unanimous in their desire to have all cars on a radio channel able to listen to both sides of all conversations and to have a capability for car-to-car communications.

Interagency Communications: The police require an intermunicipality communications capability on the dispatcher's level rather than on a car-to-car basis. In many areas, this capability has been achieved with fixed station radio equipment.

Convenient Portable Radios: Police are unanimous also in their desires to extend their radio networks beyond the restriction to mobile equipment to include small, inexpensive, portable radios which can be used by the foot patrolman and by the officer when away from his car.

Digital Communications: Many police have expressed a need for teletype in the car so that long messages can be transmitted and recorded automatically. The primary difficulties in providing this feature has been the high cost of the equipment.

THE SPECTRUM CONGESTION PROBLEM

There is general agreement that severe spectrum congestion exists in the police radio bands, and that this congestion extends across all the radio bands used in land mobile applications. The individual examples are numerous enough and are drawn from enough separate parts of the country to be convincing in spite of the lack of an overall, thorough, and detailed field measurement investigation.

The indications from limited field tests undertaken by the FCC in Los Angeles and New York, from the preoccupation with the subject in the APCO Bulletin,[2] from the study made by the Land Mobile Section of the Electronic Industries Association,[3] and from evidence gathered and presented in connection with various dockets [4, 5] that the FCC has opened in recent years point to serious congestion and a growing demand on the part of all organizations which use radio in land mobile applications. Commissioner Cox of the FCC, in a recent article addressed to the engineering profession,[6] pointed out the rapid growth in the Land Mobile Services—from 10,000 licensed transmitters in 1948 to over 220,000 in 1965—and the reasons for creation of the Advisory Committee for Land Mobile Radio Services. The need for action in this area has also been pointed out in Congress.[7]

There is a large number of examples of the effects of the spectrum shortage. Until recently, in New York City, communication for 2,000 police mobile units was provided by 8 simplex radio channels. The Bronx is patroled by about 225 mobile units, all using a single frequency channel for communications. New York City has put 500 police cars on the street without radios because of frequency shortages. In peak evening hours police in cars must use telephones to contact headquarters in order to leave radio free for dispatchers to send messages. This situation is now being relieved by the recent assignment of forestry frequencies to the New York police.

In suburban northern Illinois,[8] one network in south Cook County has 35 base stations and 200 mobile units on 1 frequency. Illinois State Police in Cook County have 200 police mobile units on 1 frequency. Their radio traffic volume for 1965 was reported as 374,000 to 500,000 messages, annually—an average of 1 message every 80 seconds for the entire year. Fifteen municipalities north of Chicago must support a total of 306 police mobile units on a single frequency. West of Chicago, 25 communities must support a total of 231 police mobile units on a single frequency, which also is shared by nearby Gary, Ind.

In southern California, 6 cities [9] in eastern Los Angeles County with a total population of 250,000 share a single radio frequency. Eight cities in the South Bay area of Los Angeles County, including the large and growing city of Torrance (population 120,000), share a single police radio frequency. The city of Los Angeles has been unable to obtain two additional frequencies, one for city-wide emergency and the other for emergency tactical control.

Consider first the situation with regard to the measure of what is needed. Actual channel loadings, that is,

[1] These cost estimates were supplied by Deputy Chief Davis of the Los Angeles Police Department.

[2] Bulletin of the Associated Public Safety Communications Officers, Inc., K. F. Conroy, editor, 38506 Lakeshore Drive, Harrison Township, Mount Clemens, Mich. 48043.

[3] Land Mobile Section of the Electronic Industries Association, "Study of the Federal Communications Commission Frequency Cards," 1964.

[4] "In the Matter of—An Inquiry Into the Present and Future Requirements of the Public Safety Radio Services for the Allocation of Radio Frequencies," FCC Docket 11997.

[5] "In the Matter of An Inquiry Into the Optimum Frequency Spacing Between Assignable Frequencies in the Land Mobile Service and the Feasibility of Frequency Sharing by Television and the Land Mobile Services," FCC Docket 15398.

[6] Kenneth A. Cox, "The Land Mobile Radio Services," IEEE Spectrum, vol. 2, No. 10, October 1956, pp. 42–43.

[7] John D. Dingell (16th District, Michigan), "The Need for Additional Radio Frequencies," Congressional Record, House, Sept. 28, 1966, pp. 23207–23216.

[8] Cook, Lake, DuPage, McHenry, and Will Counties.

[9] Pomona, Claremont, LaVerne, Covina, Azusa, and Glendora.

measurements of the percentage of time a radio channel is busy, would be indicative of the extent of the crowding. Naturally, the traffic loading in police radio channels varies, the channels being most busy in the evening hours and on weekends. An average loading of about 50 to 60 percent, however, indicates an extremely busy channel.

Surveys made by members of the Science and Technology Task Force have shown that a wide variation in police radio channel loadings exists. In one major city several channels were heavily loaded while one was very lightly loaded. Because of the inflexible design structure of police radio networks, there was no way that the city could easily switch channels from one set of users to another to use the lightly loaded channel to ease the total radio traffic burden. In many other cases, small municipalities were found to have lightly loaded (3 to 5 percent) channels although these municipalities were adjacent to a number of other cities with badly overloaded facilities. Thus, radio channel loading averaged over a metropolitan area is not a clear-cut indicator of the spectrum congestion.

Approximate rules of thumb for radio channel requirements might be arrived at on the basis of population. Sample statistics taken in the course of the work indicate that on the average, over a 24-hour day, a police patrol vehicle receives about one call per hour.[10] Further, on the basis of annual calls for police service from the public, it appears that it takes a population of about 25,000 to generate the average 1 call per hour for a mobile patrol vehicle.[11] Thus, very tentatively and subject to a more detailed evaluation, it may be said that it takes at least 1 patrol vehicle on the street at all times for each 25,000 of population. Further, studies by the Rand Corp. indicate that a police conversation lasts on the average from 25 to 60 seconds. This checks well with the viewpoint accepted by the FCC that about 30 mobile vehicles make an average load for a single radio channel. Finally, these figures are based on an average loading, but a communication system must be designed for the peak load. Assume a 5:1 ratio between peak and average loading. Thus, the figures would indicate the assignment of 1 police radio channel for mobile patrol purposes on the basis of 30 cars per channel for every 150,000 in population. The needs for supervisory vehicles, detective channels, and other special purpose channels would increase this number.

An alternative method of arriving at a population rule of thumb is as follows. Assume an average of 2.5 police personnel per 1,000 population. Assume further that half of the force is on mobile patrol beats. Using one-man patrol cars, it takes about five police patrol personnel for 24-hour coverage of a beat. This leads to a figure of 1 patrol beat per 4,000 population. In the preceding approach when peak to average loading is considered, a figure of 1 patrol car per 5,000 population was obtained. Again assuming 30 cars to a radio channel leads to the assignment of 1 radio channel per 120,000 population.

Although the two rules of thumb are in good agreement, neither should be relied upon to provide more than just additional insight into the problem area. When one considers that municipal, county, and State police operate over the same area and that the size of cities, though varying greatly, has no relationship to the area that can be covered by a radio transmitter, it becomes difficult to consider applying any rational guideline to determining the actual police radio needs of an area unless, for first approximations at least, the municipal boundaries are ignored. The approach that is taken instead is to develop, through policy decisions on spectrum assignments by the FCC, a basis for projecting future needs based upon present usage and upon the particular conditions of the local area involved.

The approach of projecting from present usage, as a base, is essentially long term in its implications. In the near term, immediate answers are required. Therefore, to supplement the long-term program, it is urged that the FCC take immediate steps to initiate a survey to determine the requirements of the police for the immediate future for additional radio spectrum.

POTENTIAL FOR ADDITIONAL RADIO SPECTRUM ALLOCATIONS FOR POLICE USE

THE NEED FOR IMMEDIATE ADDITIONAL RADIO SPECTRUM

Despite the fact that the police community can make more efficient use of the radio spectrum than it is presently doing, it is evident that such actions will not eliminate the necessity for allocation of additional frequencies for police mobile radio use.

The police forces of the nation today are basically mobile forces. The citizen's access to these forces is usually the telephone call to the radio dispatcher. It follows that police with inadequate radio communications are simply ineffective and working in the dark. No amount of computers, advanced training, or increased number of vehicles can substitute for an adequate radio network.

Further, the point was made that there is a pressing need for quantitative projections of the police radio spectrum needs over at least the next decade. Although the need for a careful evaluation of the situation is thus conceded, time is a factor. There will be no hiatus in local emergency situations while the police wait for the radio spectrum problems to be solved. Hence, while a series of recommendations are put forward, designed to encourage more efficient spectrum usage and develop projected needs, it has been concluded that steps should be taken immediately to provide additional radio spectrum resources for police use. The present section considers the divisions of the radio spectrum and the sources from which police might obtain additional frequencies.

After a review of allocations within the nongovernment bands in the United States, it is seen that there is a great disparity between the amount of spectrum space available for TV broadcasting and that available for public safety needs. The disparity is far greater than that which could be explained by the greater bandwidth requirements of TV. It is unfortunate that the police are ham-

[10] FCC Docket 11997, "Preliminary Statement," p. 19.

[11] Based on data derived from City of Chicago.

pered by inadequate radio communications while large portions of the TV spectrum are underutilized. Recommendations are made for remedying this situation, recommendations which should have only minor effect upon the radio spectrum capacity available for TV but which should provide immediate and major measures of relief for the police community.

PRESENT DIVISIONS OF THE RADIO SPECTRUM

The broad features of spectrum allocation are: about 27 percent of the spectrum is reserved for government use, 58 percent is reserved for nongovernment use and 15 percent is shared between the two. Of the nongovernment share, 88 percent is reserved for broadcasting. The mobile radio bands are about 5 percent of the total available for nongovernmental use.[12]

The usage of the mobile bands has been characterized by a phenomenal growth in the past 15 years. The causes of this growth are complex, including the general business growth, the characteristics of a nation "on the move," and the policy of the FCC in recent years of encouraging maximum use of the radio spectrum potential. The Business Radio Service, first established in 1958, had over 220,000 transmitters authorized in its first 3 years of service. The police had approximately 5,000 licensed transmitters in 1949; today they number over 200,000. It is this rapid growth that has led to the severe crowding in the mobile bands.

The FCC has allocated three basic bands to the mobile users. While generally insufficient analysis and experimentation has been carried out in the mobile bands, as compared with the government military bands or the broadcast bands, the Bell System did publish [13] a fundamental comparison of the relative desirability for mobile use of the three bands.

OPTIMUM CHOICE OF FREQUENCIES FOR POLICE MOBILE RADIO NETWORKS

As indicated in table D-1 the police community prefers the "high band" or VHF frequency range. As more efficient police mobile networks are developed, there will be a strong tendency for the police to ask for additional frequencies in the range they are using in order to minimize the changes required in their existing equipment. This trend can be already seen in cities which have designed for multifrequency transceivers—Los Angeles, Chicago, and Washington, D.C. Hence, there will be a tendency for the police to desire additional allocations in the VHF band.

The Bell Laboratories ran a series of experiments in New York to find the optimum range of frequencies for the Land Mobile Service. Their results were reported by Young.[14] These results are summarized here in a series of graphs derived from the Bell System article. Figures D-1, D-2 and D-3 show that transmission efficiency decreases with frequency but noise also decreases. As a result of these counteracting phenomena there is a broad optimum located around 450 KHz. Thus, the police might obtain somewhat superior service using this band rather than high band. The preponderance of present equipment however, favors the continued use of high band.

FIGURE D-1. MEDIAN VALUES OF RECEIVED SIGNAL POWER AT SUBURBAN LOCATIONS
(Assumes the same power at all frequencies radiated from a dipole and received on a quarter-wave whip)

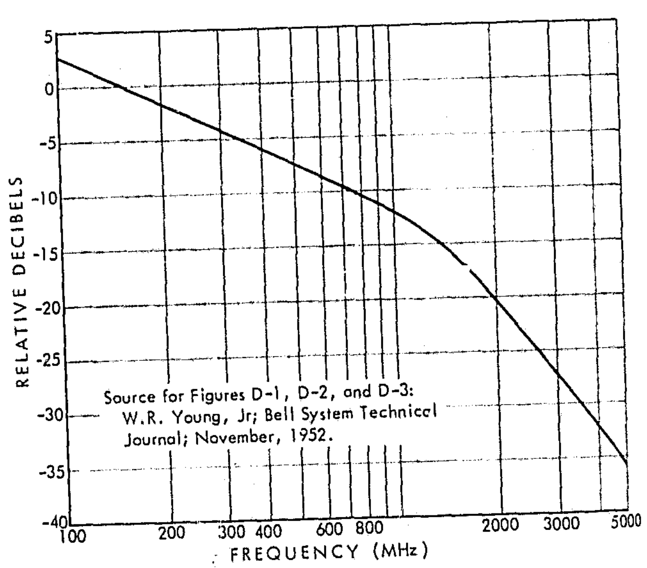


Table D-1.—Characteristics of Police Frequency Bands

Band in which police frequencies are located	Bandwidth	Noise or interference characteristics	Distance characteristics	Comments
37–46 MHz (low band)	20 kHz	Vulnerable to "skip" interference and ionospheric noise, particularly in years of high sunspot activity.	Very good reception over long distances	Interference makes this band undesirable.
154–159 MHz (high band)	30 kHz	High noise levels, particularly in urban locations.	Good distance characteristics	Generally this band preferred by police.
453–459 MHz	50 kHz	Lower noise levels than high band in urban areas.	Poor distance characteristics	Police move reluctantly to this band because of higher costs and incompatibility with high band equipment.

[12] Estimates provided in informal correspondence by W. E. Plummer, Office of Telecommunications Management.

[13] Young, W. Rae, Jr., "Comparison of Mobile Radio Transmission at 150, 450, 900, and 3700 Mc.," Bell System Technical Journal, November 1952, pp. 1068-1085.

[14] W. R. Young, op. cit.

FIGURE D-2. MEDIAN VALUE OF SIGNAL REQUIRED TO OVERRIDE NOISE

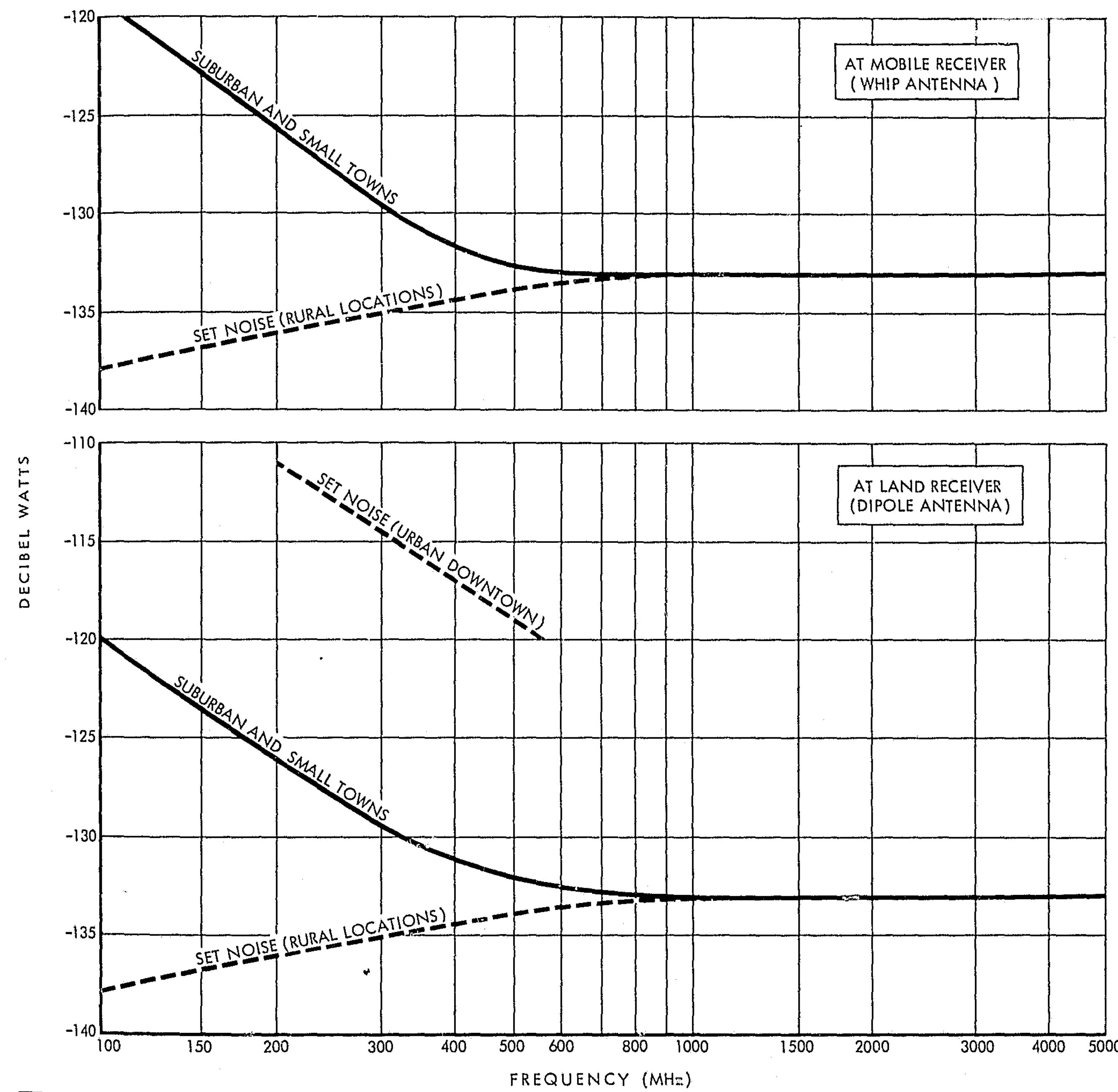
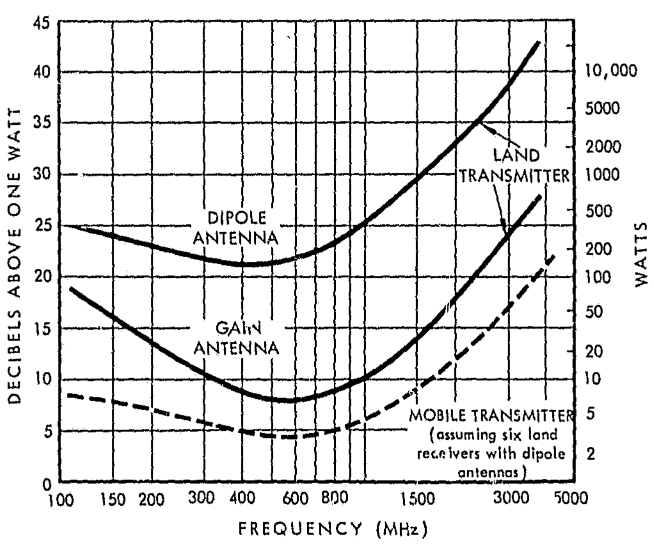


FIGURE D-3. TRANSMITTER POWER AT ANTENNA INPUT REQUIRED FOR URBAN AND SUBURBAN COVERAGE

(Mobile antennas are assumed to be quarter-wave whips)



It is generally agreed that lowband, with its skip interference, is undesirable for police use although major police departments—Baltimore County, Md.; Fairfax County, Va.—are among those still operating in this band because of the spectrum shortage. Section 89.101 (g) of FCC rules advises users in the Public Safety Services to use frequencies in the higher portions of the spectrum because they are not subject to skip interference from distant stations due to reflection off the ionosphere.

REALLOCATION POTENTIAL WITHIN THE PUBLIC SAFETY BANDS

Table D-2 provides a picture of the spectrum crowding in these bands in a very general way since it considers all the transmitters licensed all over the country. It is valid as a general picture, however, since most mobile band users, with a few notable exceptions, experience the most severe crowding in the same places—the population centers.

Since the police suffer more severely from congestion than the other Public Safety users it appears to be sensible to afford them relief by reallocation from the other user allocated bands. These other bands are also well used, however, and a more practical approach would seem to be that the user identification within the Public Safety Bands be eliminated and local governments be made responsible for the efficient usage of *all* their assigned frequencies. This would eliminate the need for further consideration of reallocation within the Public Safety Bands.

Table D-2.—Relative Congestion Among Users of the Mobile Bands

	Number transmitters per frequency
Public Safety:	
Fire	933
Forest conservation	905
Highway maintenance	699
Local government	451
Police	1,427
Special emergency	743
Overall average	975.6
Other than Public Safety:	
Auto emergency	851
Business radio	2,010
Forest products	174
Manufacturers radio	555
Motion picture radio	43
Motor carriers	319
Petroleum	396
Power	1,473
Railroad	2,000
Relay press	560
Special industrial	3,095
Taxicab	3,608
Overall average	1,306.6

Note.—From EIA study of FCC frequency cards. Only considered transmiters between 30–50, 105.8–162, 450–460 MHz.

REALLOCATION POTENTIAL WITHIN THE LAND MOBILE BANDS

Table D-2 indicates that the commercial-industrial portion of the Land Mobile Bands are, on the average, as heavily congested as the Public Safety portion. Hence, there is little possibility of additional spectrum resources being made available to the police from this source. Indeed, the commercial and industrial usage of the radio spectrum has grown so rapidly in the past two decades, that business interests can be expected to compete actively with the police at such time when additional radio spectrum is made available.

REALLOCATION OF PORTIONS OF THE BROADCAST BANDS

The overwhelming percentage of the radio spectrum allocated to broadcasting suggests this as the most promising source of additional frequencies for police. Further, consideration of the present very light usage of the UHF TV spectrum reinforces this preliminary conclusion.

The FCC, on its own initiative in 1957, instituted an inquiry [15] into the allocation of frequencies in the range 25–890 MHz. As a conclusion to that docket, the FCC determined that the following actions could be taken:

The FCC proposed to institute a trial under which certain land mobile licenses in the State of California in certain services would be given secondary sharing rights to unused frequencies of other services. The matter was investigated under docket 15399 and the region of experimentation was broadened to include Texas and the city of Chicago under docket 16259. The matter has been terminated in view of a broader proposal being considered by the Advisory Committee for the Land Mobile Radio Service.

The FCC proposed in docket 15398 to examine the feasibility of permitting the Land Mobile Service to share TV channels 2 through 13 with television broadcasting. This subject is under active examination.

[15] FCC Docket No. 11997.

The FCC instituted a study of the technical and administrative steps which might be taken to resolve problems confronting the land mobile services.

The conclusion was reached in docket 11997 that the future needs of both educational and commercial TV depend upon the maintenance of the UHF TV bands. This conclusion is commented upon later when it is pointed out that a parallel study of future needs for TV *and of future needs for Public Safety* is required to assess the relative allocations that should be made.

The trend has, however, clearly been toward an examination of the possibility of usage of TV frequencies and an examination of the allocation and assignment processes themselves as the two most significant sources of relief in the present congested spectrum situation. Here attention is directed toward an evaluation of the availability of radio spectrum in the TV broadcast bands.

Sharing the VHF TV Bands

The FCC indicated in its conclusions to docket No. 11997 that while the possibility of moving all of TV to the UHF region had not been completely ruled out, the probability of doing so appeared to be remote. Submitted as testimony in docket 15398 was a detailed engineering statement on the technical feasibility of sharing the VHF TV bands with mobile users. Although the results are conceded to be technically sound, the National Association of Broadcasters has objected on the grounds that although "some theoretical sharing may seem possible based upon hypothetical engineering assumptions, the institution of appropriate safeguards to prevent interference to television reception would undoubtedly preclude the practical assignment of land mobile stations on TV channels." [16]

The engineering analysis of the Electronic Industries Association (EIA) pointed out first that other services already operate adjacent to VHF TV channels. See table D-3.

According to the EIA analysis, the above services operate in the same area as the neighboring TV channels without causing serious problems, except for the 171–174 MHz band in areas where TV channel 7 is used. Thus, there is a basis for presuming that the same could be true of land mobile base station transmitters operating at adjacent frequencies in the same area.

Figures D-4 and D-5, taken from the EIA analysis, are the composite graphs of VHF TV receiver characteristic curves for a low-band channel, channel 5, and for a high-band channel, channel 11. These curves, which show the level of interference noticeable to the viewer, show that, as expected, the receiver is most sensitive to interference within the channel rather than to interference in neighboring channels. Further, the receiver is more susceptible to interference in the channel *below* the channel to which it is tuned than it is to interference from above. The figures specifically consider the interfering effect of a CW or narrow-band, land-mobile transmitter signal. In most cases, for adjacent channel signals, the interfering signal must be above the TV signal level, which is taken here as 225 microvolts, to cause noticeable effects. This is expected TV-signal level at the edge of the grade B service contour. Figure D-6 shows that if the land-mobile transmitter signal is kept 55 db below the 225-microvolt reference, there would be no interference to the TV even at band edge.

Figure D-7 shows the various frequencies that must be avoided in the land mobile services to minimize the possibility of local adjacent-channel television interference. The video and audio carrier should be avoided to minimize interference to the land-mobile receivers. A land-mobile transmitter on the upper channel sound beat frequency—"B" in the diagram—will mix with the upper channel video carrier which is 4.5 MHz away to produce 4.5 MHz sound I.F., which will cause audio interference in the upper channel. Similar interference effects are caused by transmissions on the other frequencies indicated in figure D-7.

As a result of their analysis, developed more completely in the referenced EIA analysis, the EIA recommended land mobile frequency assignments shown in figure D-8 for adjacent channel operation. Further, they recommended at this time that operations in adjacent channels be limited to fixed stations.

As an illustrative example of the Los Angeles situation, table D-4 shows the number of land mobile stations that might be assigned in that area on the basis of adjacent channel operation. A total of 307 25-kHz channels is available.

Table D-3.—Bands Adjacent to VHF TV

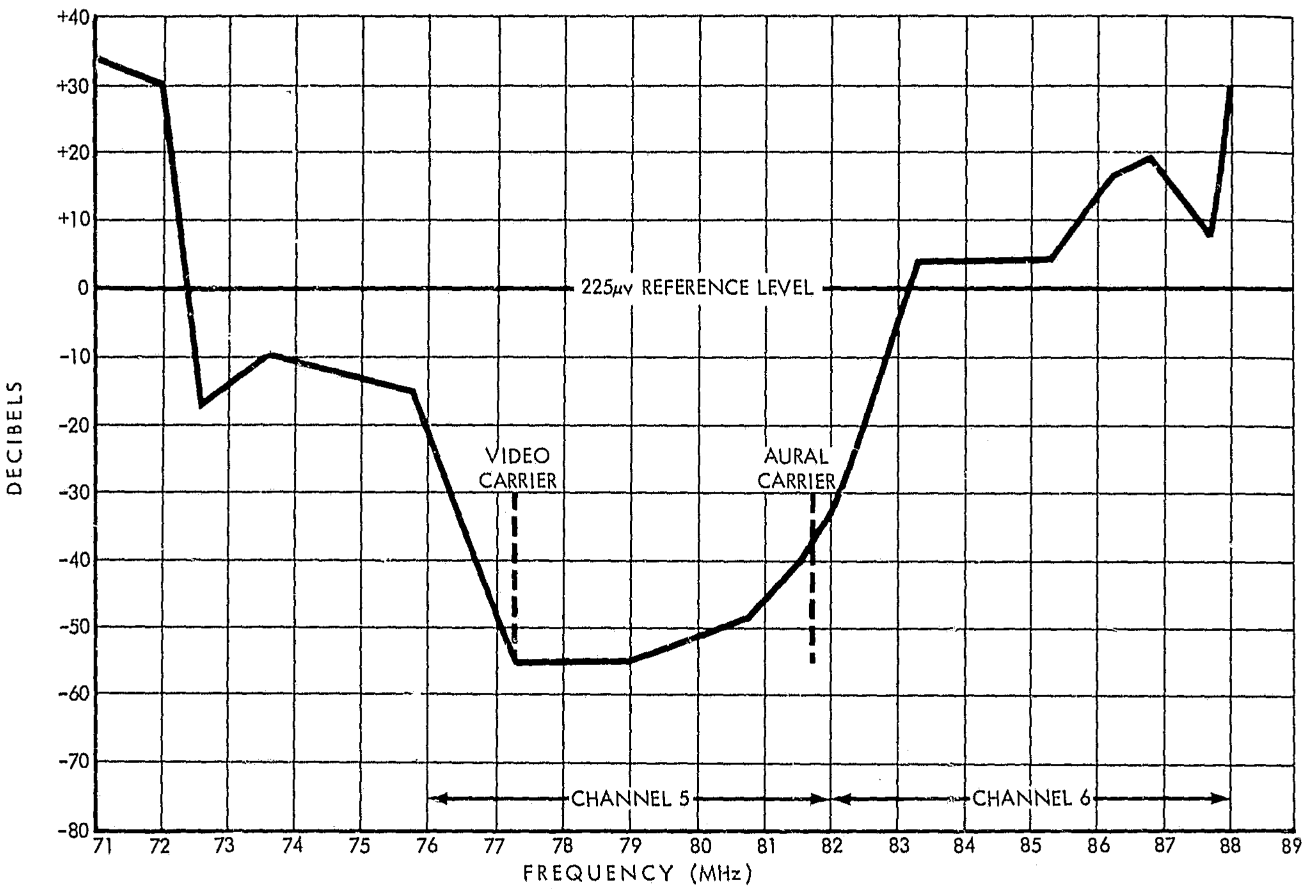
Television		Adjacent users	
Channel	Frequency (MHz)	Band	Frequency (MHz)
2	54–60	Amateur	50–54
6	82–88	FM broadcast	88.1–94.1
7	174–180	Safety and special services	168–174
13	210–216	Government and amateur	216–222

[16] Reply comments of the National Association of Broadcasters, FCC docket No. 15398, p. 4.

Table D-4.—Land Mobile Channels Available in Los Angeles in VHF TV Bands

TV channel in Los Angeles area	Adjacent channel available		Number of assignable channels (25-kHz)
	Number	Frequency (MHz)	
2	3	60–66	42
4, 5	6	82–88	139
7	8	180–186	42
9	10	192–198	42
11, 13	12	204 210	42

FIGURE D-4. TV RECEIVER INTERFERENCE REJECTION - CHANNEL 5
(Composite of all receivers tested)



The analysis in favor of the practicability of sharing is considered to be sufficiently sound and valid in its development, and the need is sufficiently intense that the matter can be expected to be amenable to decision at an early date. On the basis of the foregoing, it is recommended to the FCC that the field investigation of the practicability of sharing VHF TV spectrum with mobile users be given top priority and that when the technical conditions for sharing have been established, an appropriate portion of those spectrum resources be made available to the police community.

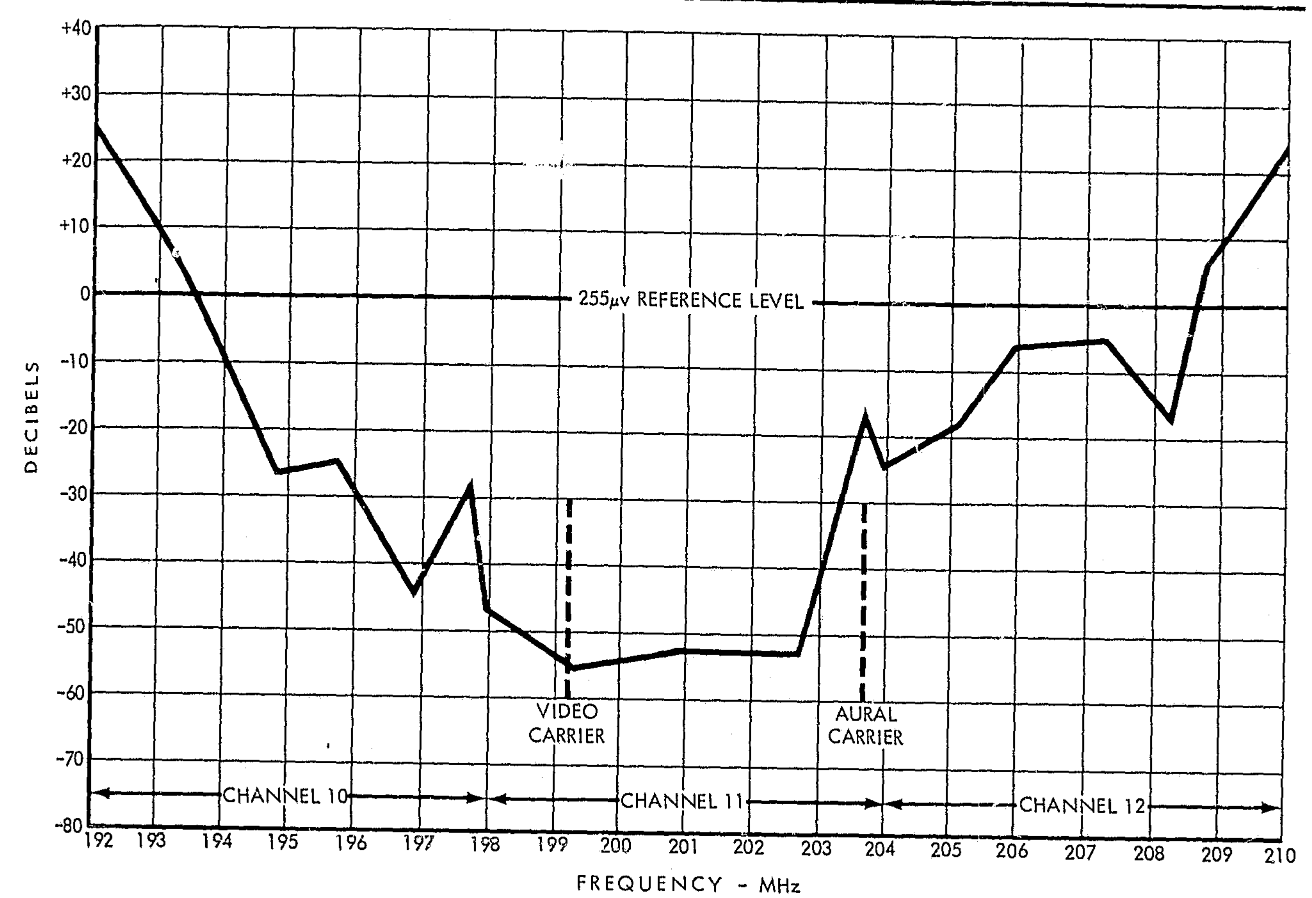
Reallocation of UHF TV Spectrum Space

Table D–5 shows the very large amount of radio spectrum space that is devoted to UHF TV. While there is currently intense interest in the potential utility of this portion of the spectrum for educational TV, the fact nevertheless remains that it represents an enormous amount of spectrum—enough for 14,000 30-kHz mobile radio channels. Just one TV channel provides sufficient bandwidth for 200 such channels. Finally, simple arithmetic shows that a reallocation, for example, of two UHF TV channels would reduce that total capacity by less than 5 percent. It is extremely doubtful whether it is possible to project the future growth of UHF TV to within this order of accuracy. Accordingly, it is recommended to the FCC that consideration should be given to reallocating radio spectrum space from UHF TV to land mobile use.

Table D–5.—Spectrum Allocations in Brief

Frequency range	Amount of frequency space	Comment
21–216 MHz	191 MHz	Most heavily used land mobile frequencies. FM broadcast. VHF television. Aviation service. Marine services. Amateur band. Government services.
216–470 MHz	254 MHz	Land mobile frequencies. Amateur bands. Government services.
470–890 MHz	420 MHz	UHF TV.

FIGURE D-5. TV RECEIVER INTERFERENCE - CHANNEL 11
(Composite of all receivers tested)



THE EFFICIENT DESIGN OF MUNICIPAL MOBILE RADIO NETWORKS

MOBILE RADIOTELEPHONE NETWORK DESIGN CONCEPTS [17]

There are two very different and very significant gains to be made by the designing of large-scale communications networks for police and public safety use as opposed to individual networks for each small user and small municipality. The advantages in scale, or more simply, the advantages that derive from the more efficient and more even loading of the channels among users of the same kind in a large network are not available to a small network. The second feature is that gross differences in user habits provide advantage to all concerned. Thus, schoolbus frequencies and some highway maintenance frequencies are available for police and fire use in evenings, weekends, and during emergencies.

The basic approach to the optimum use of communications networks developed with Erlang's work in Denmark published in 1917.[18] The approach is simple in concept although it can become complex in mathematical formulation. Basically, the concept is that the allocation of communications channels on an exclusive basis is extremely wasteful in terms of use of resources as compared to the sharing of channel resources among a number of users.

Many studies have shown that the distribution of the number of telephone messages per hour may be approximated by a Poisson distribution with parameter L, where L is the average number of messages per hour. This distribution will be assumed for police messages. That is, $K_n(t)$, the probability that there are n police messages during a time interval of t seconds is given by:

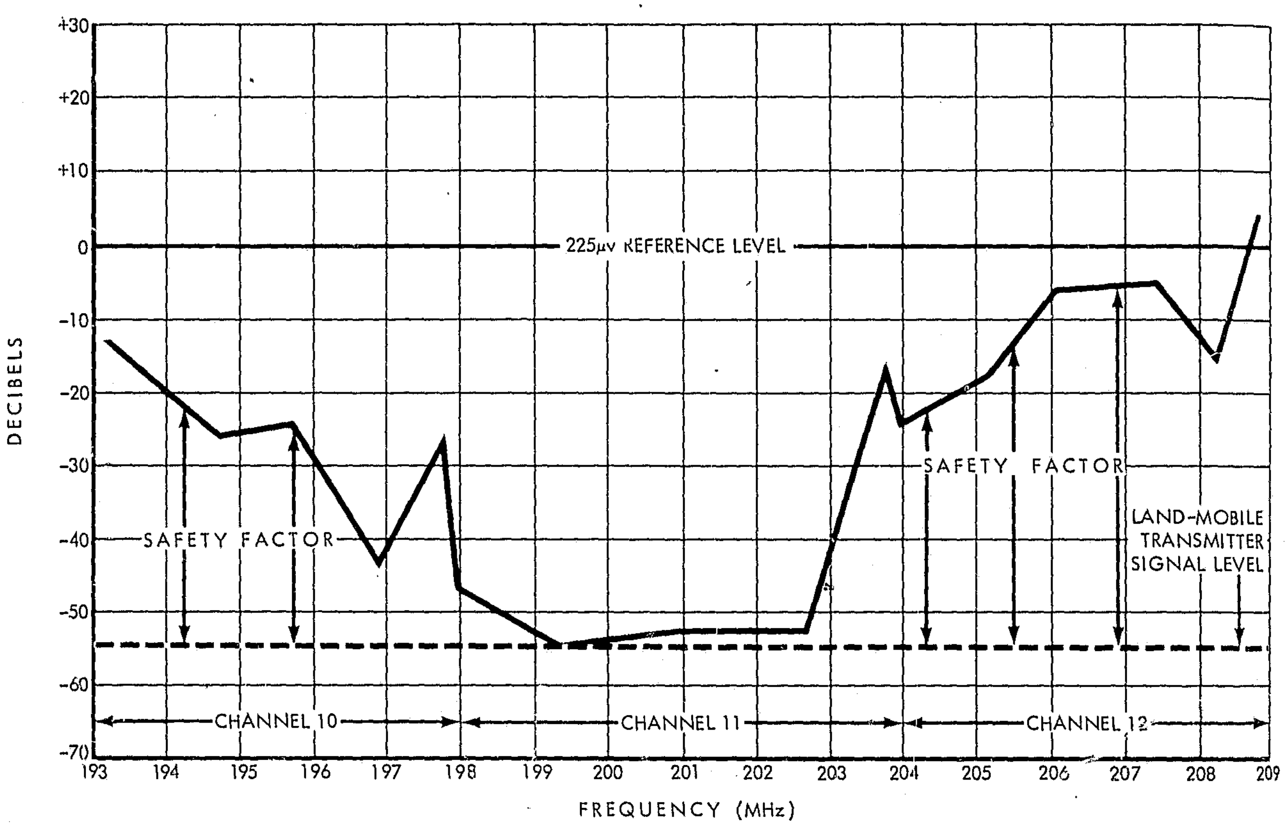
$$K_n(t) = \frac{(Lt)^n}{n!} \exp(-Lt)$$

Additionally, it is convenient to assume that the message length is a negative exponential distribution with mean $1/u$. That is, the probability that a message lasts longer than t time units is $1 - \exp(-t/u)$.

[17] Basic analysis presented here was provided by Dr. M. Bellmore of Johns Hopkins University.

[18] Brockmeyer, Halstrom, and Jensen, "The Life and Works of A. K. Erlang," Copenhagen Telephone Co., Copenhagen, 1948, contains all of Erlang's papers translated into English.

FIGURE D-6. TV RECEIVER INTERFERENCE REJECTION
(Protection against adjacent channel land mobile transmitter)



Because police communication systems have a varying load depending upon the time of day, day of week, and season of the year, different values of L must be used to represent the different time intervals during the day.

If a police department has k communications channels to divide the load and any of the k channels can be used to send a particular message, then the problem described is represented by a standard queuing model known as a k channel parallel queue with Poisson input and exponential service time.

It can be shown [19] that the mathematical model of the multichannel queue yields the following equations:

$$P_o = \frac{1}{\sum_{n=0}^{k-1} \frac{1}{n!}\rho^n + \frac{1}{k!}\rho^k \frac{k}{k-\rho}}$$

$$P(W) = \frac{\rho^k}{(k-1)!(k-\rho)} P_o$$

$$E(W) = \frac{\rho^k}{(k-1)!(k-\rho)^2} P_o \frac{1}{u}$$

where:

$$\rho = \frac{L}{u}$$

L = mean arrival rate of messages
u = reciprocal of mean service time for messages
P_o = probability that all channels are free
$P(W)$ = probability that all channels are busy
$E(W)$ = average waiting time to obtain a clear channel

The variable rho (ρ), is a measure of the communications loading and k is the number of channels. These equations may be transformed into another useful form by the substitution $\rho^* = \frac{L}{ku}$.

The variable ρ^* has the physical interpretation of the percent of total capacity that each channel is used and varies from 0 (no load) to 1 (full load).

In terms of ρ^*, the equations become:

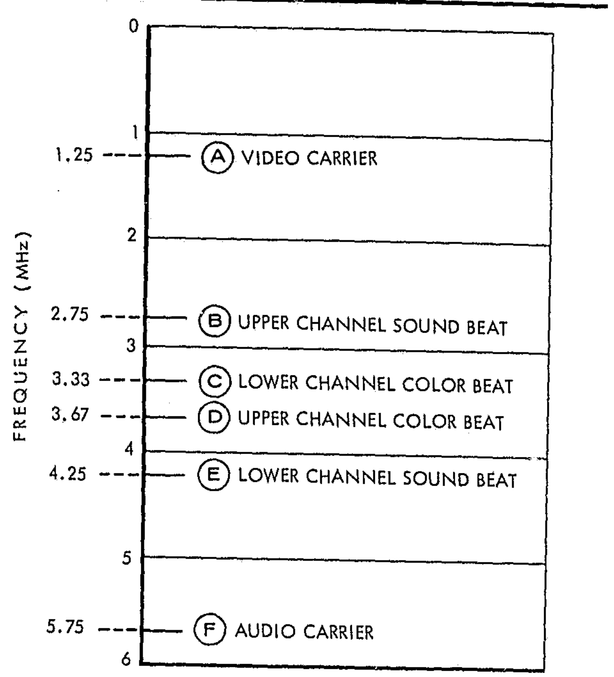
$$P_o = \frac{1}{\sum_{n=0}^{k-1} \frac{k^n \rho^{*n}}{n!} + \frac{k^{k-1}\rho^{*k}}{(k-1)!(1-\rho^*)}}$$

[19] These results may be found in almost any elementary treatment of queuing theory. See for example Sasieni, Yaspan, and Friedman "Operations Research—Methods and Problems," John Wiley and Sons, p. 138.

$$P(W) = \frac{k^{k-1}\rho^{*k}}{(k-1)!(1-\rho^*)} P_o$$

$$E(W) = \frac{k^{k-2}\rho^{*k}}{(k-1)!(1-\rho^*)^2} P_o \frac{1}{u}$$

FIGURE D-7. TV RECEIVER SPURIOUS RESPONSE PATTERN



These equations have been evaluated and the results graphed in figures D-9 and D-10. One might extend this analysis by including different classes of messages, each class with distinct u and L. In particular, one might separate the outgoing from the incoming messages, or possibly those messages from the traffic division from those messages from the patrol division. These details would be appropriate when analyzing a specific problem area.

Figures D-9 and D-10 illustrate just how powerful can be the effect of the ability to share channels. Note for example in figure D-9 that at 50 percent load factor the probability of delay in placing a call for one channel is just 50 percent. If 16 channels each busy 50 percent of the time are shared, the probability of delay reduces to below 1 percent. From figure D-10 the delay time in the first case is on the order of one service time or average message length. A message length in police work can be taken as on the order of one-half to 1 minute.[20] For 16 channels the average delay is less than 0.1 average message lengths. Why this improvement with multi-channel operation? Basically with one channel there is always a probability that the channel will be busy when a new user requests it. The probability is lower, however, that two channels will be busy at the same time. The probability is very low that a large number of channels are all busy at the same time. (These statements assume the same loading in all channels.) Hence, in a multichannel operation, the idle time of channels is used more effectively so that, as compared with use on an exclusive basis, the equipment is put to much more efficient use.

These curves are indicative rather than absolute in nature. When channels are lightly used with 10 to 20 percent loading factors, conversations tend to be lengthy and radio discipline somewhat lax. When channels are congested, 60 percent loading and above, conversations are more crisp and radio discipline is necessarily enforced. Consideration of these factors would modify the charts substantially. Nevertheless the charts indicate that, for example, at 40 percent loading with two channels trunking the service, the probability that all channels are busy is equivalent to that which would obtain from four individual channels. Trunking then can be a powerful technique for obtaining effectively better communications at no additional cost in radio spectrum space.

It should be understood that channel sharing does not mean that all users hear all messages. With modern coding techniques each police department in a channel sharing arrangement can use the radio frequency channel to address only its own cars without "opening up" the receivers of other using departments.

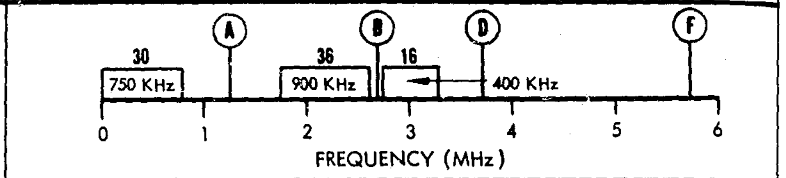
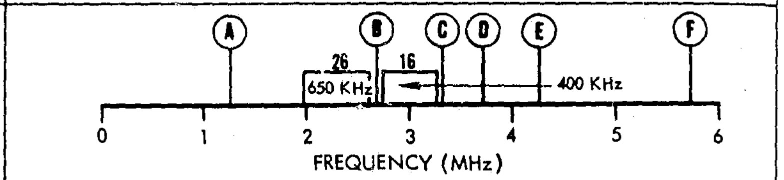
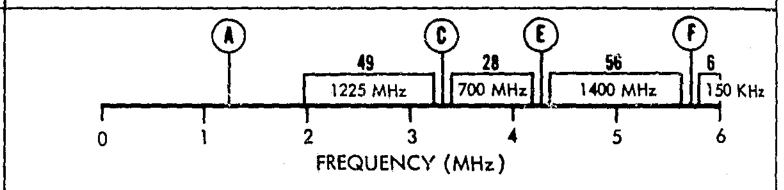
The system designs discussed here are for normal police operations including the normal increase in load on weekend evenings. There are emergency situations involving natural disasters or riots which can create severe overloads on even the largest police networks. While something can be done in such situations, such as the preemption by the police of radio frequencies normally used for other purposes, the discussion here does not consider such matters.

Thus, with no increase in the number of radio channels, communication system users can get superior service if they pool their spectrum resources into a multichannel system. The outstanding example, of course, is the telephone industry which gets good channel loading and provides superior service because of the large number of users who share a common system.

In a shared system, an individual user no longer has a unique channel. Rather he has a unique address and uses whichever channel is available at the time of his need. The unique address or radiotelephone number, is provided by means of the subaudio selective codes which have already been used to a limited extent in police mobile radio systems. In such a system of pooling, in which several municipalities may be involved in order to realize the economies of size, an individual police department retains complete control over its own forces. Its calls go only to its own cars. It surrenders no more control than it does through use of the common carrier telephone system for making telephone calls.

[20] Mr. Al Hiebert of Rand Corp. has pointed out that the usual figure of 10 seconds duration for a police call is not the correct figure to use in calculations of traffic loading and expected waiting times. A message consists of a conversation back and forth between a dispatcher and a car and consists of several transmissions of average length 10 seconds. Until now, many measurements of transmission duration have been made but virtually none of conversation length. Yet the conversation is never interrupted except in the gravest emergency. The length of a typical police conversation is taken here as 1 minute. The number is based upon inadequate statistics but indications are that the average will be within a factor of 2 of this quantity.

FIGURE D-8. LAND-MOBILE FREQUENCY ASSIGNMENT
(For 60-mile Minimum Adjacent Channel)

LAND-MOBILE TRANSMITTERS IN VHF CHANNELS	CO-AREA TV TRANSMITTERS IN VHF CHANNELS	NO. OF ASSIGNABLE LAND-MOBILE 25 KHz CHANNELS	
2, 5, or 7	3, 6, or 8	82	
3, 8, 9, 10, 11, or 12	2 & 4, 7 & 9, 9 & 11, 10 & 12, or 11 & 13	42	
4, 6, or 13	3, 5, or 12	139	

AS A REFERENCE

VHF CHANNEL	FREQ (MHz)	VHF CHANNEL	FREQ (MHz)
2	54-60	7	174-180
3	60-66	8	180-186
4	66-72	9	186-192
5	76-82	10	192-198
6	82-88	11	198-204
		12	204-210
		13	210-216

Ⓐ VIDEO CARRIER
Ⓑ UPPER CHANNEL SOUND BEAT, IM PRODUCT
Ⓒ LOWER CHANNEL COLOR BEAT
Ⓓ UPPER CHANNEL CARRIER BEAT
Ⓔ LOWER CHANNEL SOUND BEAT, IM PRODUCT
Ⓕ AUDIO CARRIER
36 NUMBER OF CHANNELS AVAILABLE

DESIGN TECHNIQUES APPLIED TO WASHINGTON METROPOLITAN AREA [21]

Present Situation in Washington Metropolitan Area

The Washington metropolitan area (fig. D–11), is defined here to include the District of Columbia, Montgomery and Prince Georges Counties in Maryland, and Arlington and Fairfax Counties, Va., and the independent city of Alexandria, Va. It is an area of approximately 1,400 square miles with approximately 2 million inhabitants. This complex comprises two States and a Federal jurisdiction.

The D.C. metropolitan police force, serving 61.4 square miles and 764,000 people, currently uses three duplex channels to control a mobile fleet of approximately 106 cars on patrol at any one time.[22] See table D–6. In addition, two duplex channels are used in a well-designed system for communicating with foot patrolmen from the precinct houses. These latter channels will not be referred to again as the need for them is peculiar to the District and the small size constraints on handi-talkies inhibits the use of multiple channels in any sharing arrangement.

Montgomery County, bordering the District to the north and west, controls approximately 40 mobile units on patrol by means of two simplex channels, reserving a third simplex channel for emergency use. The county police department is responsible for the policing of all of Montgomery County, approximately 500 square miles and 341,000 people, with the exception of the city of Takoma Park which is partly within Montgomery County and partly within Prince Georges County. Table D–7 summarizes the police radio frequency usage in the Washing-

Table D–6.—District of Columbia Police Department Radio Frequencies

Channel	Frequency (MHz)	User
1	155.250 159.030	Base. Mobile.
2	155.310 158.850	Base. Mobile.
3	155.415 159.150	Base. Mobile.
Green (Precinct Nos. 1, 2, 3, 6 8, 11 and 12).	154.80 154.920	Base. Patrolmen.
Red (Procinct Nos. 4, 5, 7, 9, 10, 13 and 14).	156.030 156.090	Base. Patrolmen.
Other	154.890 155.515 453.550	Civil disturbance. Handi-talkie. Radar handi-talkie. Metropolitan Area intersystems communication.

[21] Acknowledgment of assistance provided by Inspector McAuliffe of the Washington Metropolitan Police should be noted but not interpreted as prior approval on his part nor on the part of his organization of the viewpoint developed here.

[22] In all of the discussions here, numbers of police patrol cars are taken as equal to the number of police patrol beats or sectors and hence do not include supervisory vehicles, detective vehicles, traffic squad—if organized separately from patrol units—or undercover vehicles.

FIGURE D-9. PROBABILITY OF DELAY IN MULTICHANNEL SYSTEMS

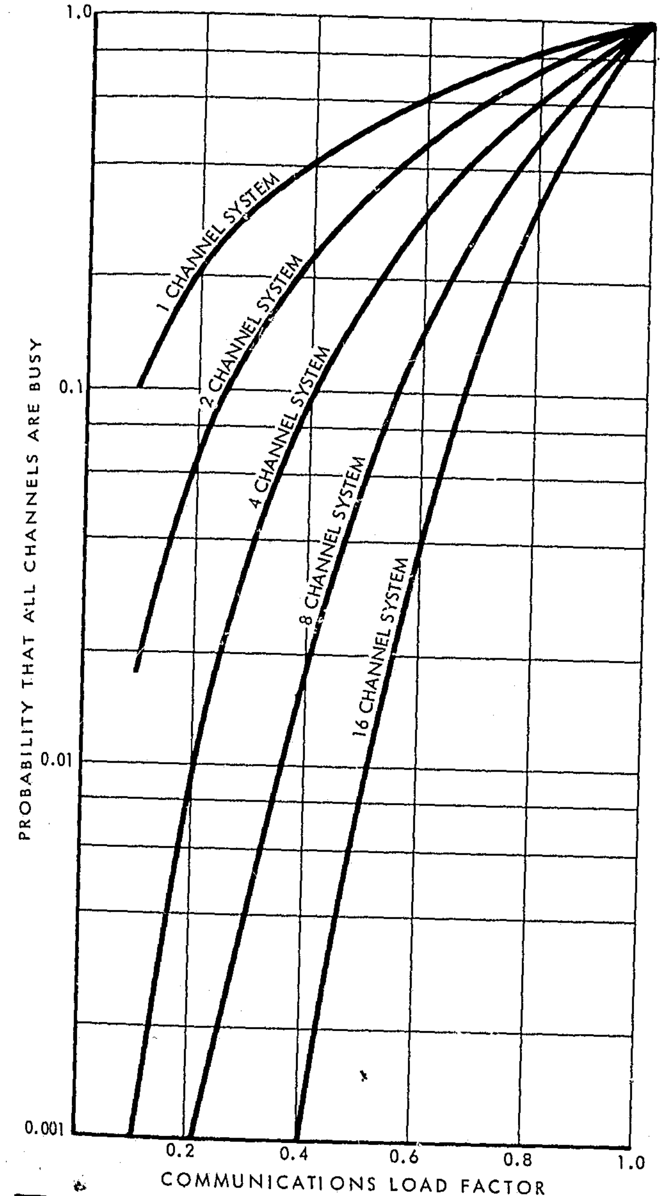


FIGURE D-10. EXPECTED WAITING TIMES IN MULTICHANNEL SYSTEMS

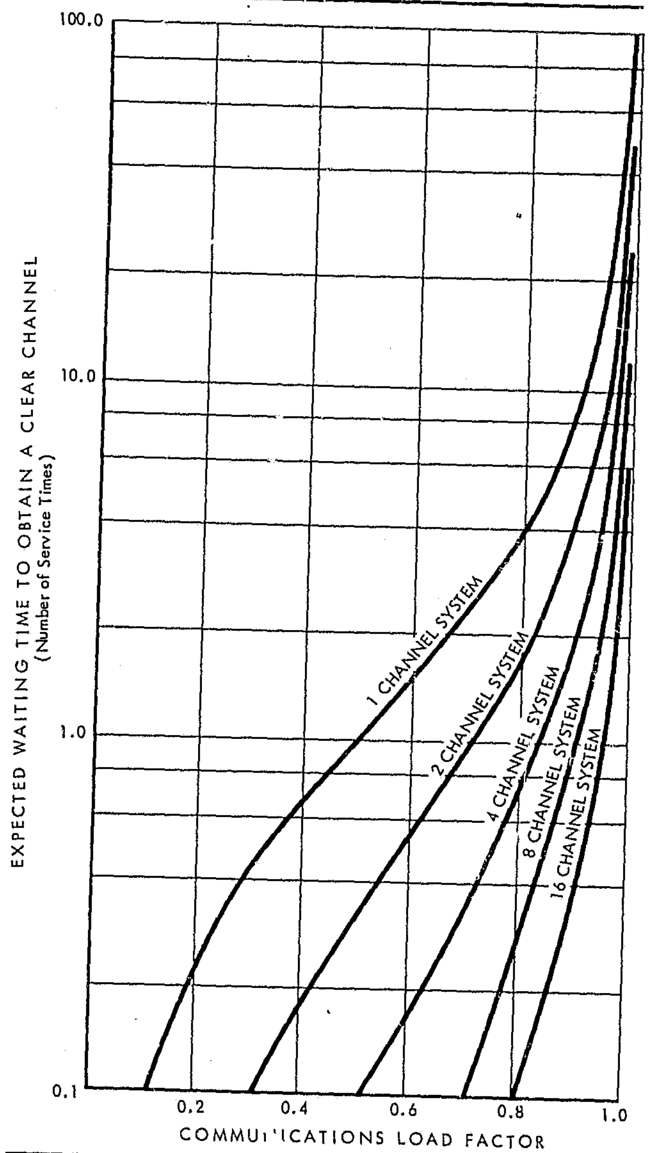
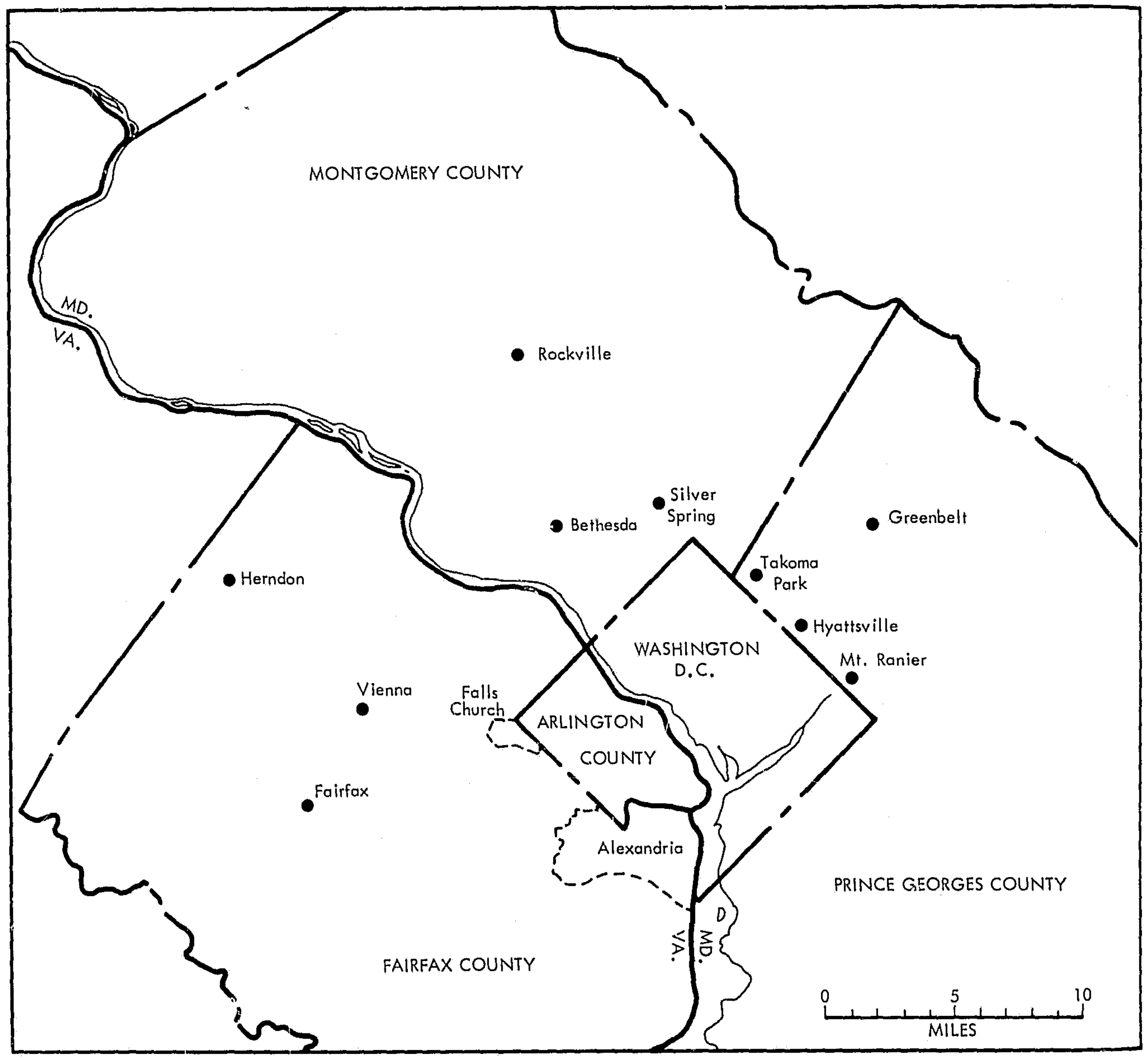


FIGURE D-11. THE WASHINGTON METROPOLITAN AREA



ton suburbs and shows the Montgomery County usage. Table D-8 summarizes the areawide situation in graphic form. On that chart, the loading figure, or approximate channel usage, for Montgomery County has been adjusted to include use of the emergency channel on a day-to-day basis. Evidently, if greater availability of communications channels is to result from channel sharing, a first step must be to even the loading of channels within an individual jurisdiction.

Takoma Park directs and controls approximately three mobile units by means of a single simplex radio channel. It is a municipality of 16,799 population (1960 census) and 2.2 square miles with a 23-man police force.

While Prince Georges County has a police force, a number of incorporated municipalities in the county have their own independent forces whose cars are dispatched by county police headquarters. In addition, the cities of Mt. Rainier, Hyattsville, and Greenbelt possess their own communications system for a small number of mobile patrol units. The county police have a relatively heavily loaded duplex communications channel which provides communications for about 50 mobile units.

Table D-7.—Suburban Washington Police Radio Frequencies

Area	Frequency (MHz)	Use
Montgomery County (5 transmitter sites; all dispatching done from Rockville.)	155.64	Channel 1, base and mobile; covers Silver Spring and Bethesda areas.
	155.52	Channel 2, base and mobile; covers Rockville and Wheaton areas.
	154.71	Channel 3, emergency.
	453.55	Intersystems communications.
Prince Georges County (3 transmitter sites; all dispatching done from Seat Pleasant.)	158.73	Base
	155.58	Mobile
	154.83	Mobile
	453.55	Intersystems communications.
Arlington County	158.790	Base
	154.740	Mobile.
	453.55	Intersystems communications.
Fairfax County	39.54	Base and mobile.
	39.66	Special channel.
	453.55	Intersystems communications.
Alexandria	155.07	Patrolmen network.
	158.97	Mobile.
	158.91	Mobile.
	453.55	Intersystems communications.
Fairfax, Va	45.98	Base and mobile.
Falls Church, Va	156.15	Base
	154.80	Base and mobile.
Greenbelt, Md	155.73	Base and mobile.
Herndon, Va	39.54	Base and mobile.
Hyattsville, Md	155.13	Base and mobile.
Mt. Rainier, Md	154.95	Base and mobile.
Takoma Park, Md	39.82	Base and mobile.
Vienna, Va	155.70	Base and mobile.

In Virginia, there are three major police departments, those of the counties of Arlington and Fairfax and the city of Alexandria. Arlington, a suburban county of 163,401 population (1960 census) and approximately 30 square miles communicates with approximately 46 mobile units in the field by means of a single duplex channel. Alexandria, with a population of 91,023 (1960 census) and 15 square miles of area communicates with 16 mobile field units with a single duplex channel. This channel has a mobile repeater feature so that the officer's conversation with the dispatcher is repeated out over the dispatcher's channel so that all cars hear all parts of a conversation. In addition, Alexandria has a small network of hand-carried radios for use by patrolmen.

Fairfax county is composed of approximately 275,000 people in 325 square miles of Washington suburban communities surrounded by farm country. It is policed primarily by the county police who field 20 police mobile units and communicate with them by means of a single simplex channel. The traffic loading figure for the county police has been adjusted to include use of the special police channel on a day-to-day basis. A number of small towns in Fairfax County provide communication channels for their own mobile forces. These include Fairfax City, Falls Church, Vienna, and Herndon.

The loading for Fairfax County has been adjusted to include usage of a special channel on a day-to-day basis. This may be somewhat unrealistic since the county is sufficiently large that the special channel may be required sufficiently often as to be unavailable for control of mobile forces when needed. Nevertheless, the unmodified load is 67 percent and this figure results in such lengthy delays in placing messages—on the order of 2 minutes—that the additional channel should be used when available. These two channels are also available to Herndon.

Optimization of Washington Metropolitan Area Police Communications—On a County Basis

As a first step in considering the possibilities for a more effective police mobile communications system for the Washington metropolitan area, consider the coordination of all such communications within the jurisdictions of the individual counties in this area. For realism, it can be assumed that there is no transfer of radio spectrum resources across county lines, but that complete cooperation within an individual county is expected.

Under the above ground rules, integration of the duplex channels of Washington, D.C., would result in the improvement indicated in table D-9. The communications facilities of Montgomery County are already integrated on a countywide basis with the exception of Takoma Park. For simplification, in this model, Takoma Park will be included with Prince Georges County.

In Prince Georges County, the mobile police communications facilities of Takoma Park, Mt. Rainier, Hyattsville, and Greenbelt are to be combined with those of the county. To the integrated facility, the following frequencies are available:

Facility	*Frequency (MHz)*
Prince Georges County	154.83
	155.58
	158.73
Greenbelt	155.73
Hyattsville	155.13
Mt. Rainier	154.95
Takoma Park	39.82

Accordingly, the integrated system, as shown in table D-9, may be designed to have 3 duplex channels to handle the approximately 65 cars on patrol in the county. This would be an entirely adequate system for all normal purposes and would provide improved performance for *all* police in the county as is shown in table D-10.

The loading on the new system was estimated by noting that the *average loading* on five channels previously was 14.4 percent. Converting this to a three-channel system yields 24 percent average channel loading in the new system. Note, from the table, that this loading for a three-channel system results in very efficient service.

It may appear that Mt. Rainier did not particularly benefit from the change to a countywide system. Note, however, that their communications facilities, originally one channel for an average of two cars, were entirely adequate and continue to be so after the consolidation. In addition, the small Mt. Rainier force is now tied in with a larger capability and may tap those larger resources when the situation requires.

The example just presented of an integrated police mobile communications system for Prince Georges County is valid from the viewpoint of systems engineering but has some shortcomings in terms of component or subsystem design. Suppliers of mobile radio equipment prefer

TABLE D-8. - SUMMARY OF CURRENT POLICE SPECTRUM LOADING IN WASHINGTON METROPOLITAN AREA

User Original Position	Diagram	Load	No. Mobiles on Patrol at One Time (approx.)	Modified Load (See Text)	Probability of Delay	Expected Delay (Seconds)
Washington, D.C.	155.250 [D] 159.030 155.310 [D] 158.850 155.415 [D] 159.150	37%	106	----	.37	36
Montgomery County (Integrated)	[D] 155.64 [D] 155.52 (Emergency) [D] 154.71	55%	40	36%	.11	4.5
Takoma Park	[D] 39.82	6%	3	----	.06	4.2
Prince Georges County	158.73 [D] 155.58 / 154.83	50%	50	----	.50	60
Mt. Rainier	[D] 154.95	2%	2	----	.02	1.2
Hyattsville	[D] 155.13	8%	5	----	.08	5.4
Greenbelt	[D] 155.73	6%	3	----	.06	4.2
Arlington County	158.790 [D] 154.740	50%	46	----	.50	60
Alexandria	155.07 [D] 158.97	8%	16		.08	5.4
Fairfax (City)	[D] 45.98	13%	2-3	----	.13	7.8
Falls Church	156.15 [D] 154.80	14%	4	----	.14	8.4
Vienna	[D] 155.70	3%	3	----	.03	1.8
Herndon[1]	[D] 39.54	67%	1	33%	.16	7.2
Fairfax County	[D] 39.54 [D] 39.66	67%	20	33%	.16	7.2

[1]Shares channel with Fairfax County

Code: [D] Dispatcher

Simplex Radio Channel

[D] Talk-out Half of Duplex

[D] Talk-in Half of Duplex

TABLE D-9. - POLICE SPECTRUM LOADING IN COORDINATED COUNTY SYSTEMS

User	Diagram	Load	No. of Mobile Units On Patrol at Any Time (approx.)	Probability of Delay	Expected Delay (Seconds)
Washington, D.C.	155.250 [D] 159.030 155.310 [D] 158.850 155.415 [D] 159.150	37%	106	.12	4.8
Integrated Prince Georges County	158.73 [D] 155.73 154.95 [D] 155.58 154.83 [D] 155.13	24%	65	.04	1.2
Montgomery County (unchanged)	[D] 155.64 [D] 155.52 [D] 154.71	36%	40	.11	4.5
Arlington County	158.790 [D] 154.740	50%	46	.5	60
Alexandria	155.07 [D] 158.97	8%	16	.08	5.4
Integrated Fairfax County	154.80 [D] 45.98 156.15 [D] 39.54 155.70 [D] 39.66	32%	30	.08	2.4

[1]Shares channel with Fairfax County

Code: [D] Dispatcher

Simplex Radio Channel

[D] Talk-out Half of Duplex

[D] Talk-in Half of Duplex

Table D-10.—Communications Delays Within Prince Georges County

Police department	Present communications system		Integrated County System	
	Probability of delay	Expected delay (seconds)	Probability of Delay	Expected Delay (seconds)
Greenbelt	0.06	3.7	0.04	1.2
Hyattsville	.08	5.1		
Mt. Rainier	.02	1.2		
Takoma Park	.06	3.7		
Prince Georges County	.50	60.0		

closely spaced channels in order to simplify the design of their equipment and so keep costs within limits. The frequencies available to Prince Georges County are awkwardly spaced for inclusion in a single multichannel set due to the 158.73 MHz frequency and indicate the shortcomings and the additional costs involved in pooling on a relatively small base. Thus, the economies of scale that result from coordinated communications networks are twofold. First, the efficiencies derived from channel sharing and the resulting decrease in probability of delay in placing calls are more impressive as more channels are used. Second, the larger the base for the coordination, the greater the choice of frequencies among which to select for minimizing equipment costs. Generally, these equipment considerations will not be emphasized in this discussion of overall systems design. Note that in the integrated Prince Georges County system, the 39.82 MHz (Takoma Park) channel would not be needed and hence would not be used.

Arlington and Alexandria as independent areas are not affected by the move toward consolidation of county facilities. In Fairfax County, the following frequencies are available:

MHz		*MHz*	
39.54	Fairfax County	154.80	Falls Church
39.66	Fairfax County	155.70	Vienna
45.98	Fairfax County	156.15	Falls Church

A three-channel duplex system is suggested with VHF channels used for talking out to the cars and the HF frequencies used for talking back to the dispatcher from the car. The average loading of the new system—calculated as before—is approximately 32 percent. The receiving antennas at the fixed sites should be designed for low angle coverage to selectively reject as much as possible the long-distance skip interference characteristic of the HF band; note, again, the awkward selection of frequencies.[23]

Table D–11 shows the improvement expected in Fairfax County from adoption of the suggested changes and ignoring, for purposes of illustration, the equipment problems raised by the specific frequencies involved. In all cases, except Vienna, improved performance would result from the coordination of facilities within Fairfax County. Vienna's situation is similar to Mt. Rainier's in Prince Georges County, i.e., an entirely adequate system remains so. Table D–9 summarizes the material.

Table D–11.—Communications Delays Within Fairfax County

Police department	Present communications system		Integrated County System	
	Probability of delay	Expected delay (seconds)	Probability of delay	Expected delay (seconds)
Fairfax City	0.13	9.0	.08	2.4
Fairfax County	.33	7.2		
Falls Church	.14	9.6		
Herndon	.33	7.2		
Vienna	.03	1.8		

Consideration of Area-Wide Coordination

From table D–9 it is seen that through coordination on a countywide basis the loading is relatively satisfactory for all police mobile forces, with the notable exception of the county of Arlington. The situation is somewhat artificial, however, for the following reasons:

> The frequencies included in Prince Georges County's recommended three duplex channels are spaced awkwardly for efficient equipment design; specifically, the 158.73 MHz channel should be exchanged for one in the 154 MHz region.
>
> The Fairfax County system uses HF frequencies which are generally undesirable because of skip interference.

One solution to the Fairfax County problem would be an integrated Virginia suburban system combining the city of Alexandria and counties of Arlington and Fairfax. Such a system would have enough VHF frequencies for four duplex VHF channels and would have an average loading of 39 percent, which would result in probabilities of delay less than 8 percent and expected waiting times of only 4 seconds. The frequencies available are 154.74, 154.80, 155.07, 155.70, 156.79, 158.79, 158.91, and 158.97 MHz.

Again the frequencies are spaced awkwardly and the integrated system would want to exchange 156.79 MHz for a frequency in the 158 MHz range.

In the event that such a change were made, all cars in the area would have at least three send-and-receive channels. All such systems would have duplex channels, with the exception of Montgomery County which uses simplex channels.

At this point in this simplified analysis, if the above recommendations were adopted all police mobile communications would be adequate but with neither growth capability nor the ability to accommodate additional required services such as handi-talkies and communications links away from the car. The latter requirements call for additional frequencies.

With the immediate problems at least partially solved, in this hypothetical example, consider the situation that would exist. In Virginia the police officer in his mobile vehicle, when he wished to place a call, would press the microphone button. The channel selector would locate a frequency, one of four, and he possibly would activate a switch to call his dispatcher. Upon release of the address-code switch he would call in his report. Alternately the coded address could be a part of the press-to-talk function, automatically terminating with the received reply. The opinion has been expressed by some that the police officer might prefer to make his own search for an unused frequency or might prefer a single frequency link. The manual search feature would appear to be operationally unattractive and the single frequency system leads to inefficient channel loading and inferior service. Throughout the conversation—even while listening to the dispatcher—the police officer would continue to hold the channel by leaving his transmitter on. The dispatcher similarly would hold his channel to the car by leaving his transmitter on while listening. If the police officer were part of the Fairfax County force, his conversation would not be heard by the Arlington communications systems although the radiation would cover Arlington. This latter feature is necessary in order that channel selectors in Arlington equipment could monitor that channel in order to use it when it was available.

In no sense has a complete and thorough systems analysis been made of the channel sharing concepts presented here. They do provide for more efficient spectrum utilization and for much greater flexibility in establishing connections in a police mobile radio network. By prearrangement, for example, the Arlington police could call Alexandria police cars either directly or by being patched through the dispatcher. A frequency may be removed from general service and assigned to a tactical force talking on a car-to-car basis if so required. While these degrees of freedom exist, they all involve different costs. It should not be difficult, however, with selective calling to design and implement systems which are so built that they can later be modified to accommodate additional desirable features.

The concept of multiple selection of channels must be taken as only a recommended approach for investigation until such time as the detailed design and development has been accomplished on a specific system. One feature of the system that must be extremely attractive to the police community is the ability to create special channels without putting a frequency "on-the-shelf." Thus a single areawide channel for the Washington metropolitan area could be provided by proper coding—and the proper placement of transmitters and receivers—and the frequency planned for use by that channel may be used on all occasions, except the rare ones when such coordinated networking is required, by a police department in its normal day-to-day operations. This practice contrasts very favorably with the alternative one of holding frequencies in reserve for detective work or citywide use but not having these frequencies available for general use at other times.

Critique of the Example

The example just given shows that a great deal can be done by the police themselves to alleviate their spectrum crowding problems. The solution arrived at in the specific case is by no means a perfect one. Further, it is clearly a minimal solution. While the day-to-day control of the police mobile forces would be taken care of, the system would be sufficiently loaded that there would be little real freedom for releasing frequencies for any special purposes, such as undercover or other detective functions. In addition, there are no excess frequency resources to sustain growth. The needs for handi-talkies and for away-from-the-car communications will create a demand for additional frequencies.

In certain areas of the country, it is quite evident that the spectrum shortage is sufficiently severe that any redesign of networks must be done in parallel with the assignment of additional frequencies. This is undoubtedly the case in New York City and in the suburbs of Chicago.

In addition to all of the above, the example sketched has ignored critically important cost and equipment problems.

Local political situations in any local area will also play a part in determining the configuration of network most acceptable.

It is possible only to conclude that network redesign to accommodate channel sharing will result in more efficient use of the spectrum. The effort is more likely to be successful if it is done on a wide area basis with a large number of frequencies involved, and, in any case, will probably require some trading of frequencies among users.

THE DESIGN OF PUBLIC SAFETY NETWORKS

Since the times of heaviest usage of the different public safety communications channels do not coincide, it is evident that major gains in more effective use of the radio frequency spectrum can be made by the creation of such networks combining various public safety users. While the police and fire channels are used all 7 days of the week, in the evening and night hours as well, the same is not nearly as true for highway maintenance or for local government frequencies used for miscellaneous local activities not directly concerned with public safety.

There are problems involved in designing such networks. The highway maintenance frequencies which might be made available to the police as backup frequencies for emergency purposes or for weekend radio traffic are not always contiguous with the police bands. Further, in at least one city where the possibility of a public safety communications network was considered, all of the police frequencies were in the VHF band while highway maintenance frequencies were in UHF.

Police officials generally have serious reservations about the practicability of public safety networks. Thus the police have reservations about a citywide communications system through the adoption of which they may lose some of the close control of their field forces.

A further consideration which has been raised by police communicators is that if they can acquire additional channels, as needed, from other municipal services, then the other services can make a case for using police frequencies when they face critical situations. Thus the ability to control and dispatch police vehicles becomes more nearly subject to decisions that may be made by nonpolice personnel.

There is no really satisfactory general answer to the above problem. It can, however, be answered in a detailed design. That is, in a specific design a basic set of channels can be provided for such vital operations as those of police and fire and no technical facilities provided for switching those channels out of those services. Thus the police and fire chiefs can be assured of having a basic communications capability. Other channels, of a less essential nature, can be provided on a switchable basis.

A number of counties in the country do have county public safety communications centers. Several were visited in the course of this work. While these centers provide impressive advantages in terms of centralization of maintenance and the development of openings for professional caliber personnel, they do not constitute integrated networks in the sense used here. Frequencies are still identified with usage and essentially a central dispatch

[23] Due to the small total base of frequencies used in the pooling system.

point is created for a large number of individual mobile radio networks. Nevertheless, these centers represent a distinct advance over the patchwork of small separate communications centers that exist in most counties.

Some cities, notably Los Angeles, Chicago, and New York, have such large police departments that they already have the advantages of scale needed to develop networks along the lines proposed here. In any future developments in such cities, a distinct and entirely separate police dispatching center would continue to be required.

Despite the independence of the large police communications network, however, it is still possible, even in the larger cities, for the municipal government to make channels available to the police dispatcher for use on weekends and under emergency conditions.

The possibility of viewing public safety needs from a total municipal viewpoint has important implications in terms of FCC allocations and assignments. These topics are considered separately.

THE RELATIONSHIP BETWEEN THE POLICE AND THE FCC [24]

THE POLICE/FCC INTERFACE

The *allotment* of different portions of the spectrum to different usage is carried out by international agreement. Within the United States and in the nongovernment sector of the radio spectrum, the *allocation* of bands of frequencies to different nongovernmental services is determined by the FCC. Within the framework of these allocations, *assignments* of individual frequencies to individual users, excluding agencies of the Federal Government, is then made by the FCC. The coordination of activities in the Government bands—which refers to Federal Government only since State and local government use of the radio spectrum is under FCC jurisdiction—is carried out by the Intragovernmental Radio Advisory Committee (IRAC). IRAC has a permanent staff located in the Office of Telecommunications Management of the Executive Office of the President.

In earlier years it was not uncommon for considerable sharing of frequency resources to exist on a somewhat informal basis. Before World War II the communications center of the Washington Metropolitan Police Department, as a service, dispatched police mobile units for the surrounding counties. The frequencies utilized were in the HF band and, although bothered by skip interference, they gave very broad local coverage and were convenient for dispatching distant vehicles.

In recent years, with the increased metropolitan congestion and the shift to the less interference-prone VHF and UHF frequencies, the workloads of the large metropolitan police forces have been too large to provide service to their smaller neighbors. Their coverage has been too limited to reach distant neighbors reliably. As indicated in the preceding sections, it is proposed once again to return to a system of closer intermunicipal cooperation in the interest of more efficient use of the radio frequency spectrum. The significant change proposed here, and made possible by the present state of technology, is the elimination to a large extent of the frequency itself as a means of addressing a receiver, substituting reliance upon selective codes for addressing. The frequency is then merely a communications channel available to any legitimate user as is a two-wire pair in a telephone network. The selective code is analogous to the telephone number.

To a large extent, FCC policy is in spirit already in consonance with the approach of frequency sharing. To quote from section 89.101 of the FCC Standards, the part which is concerned with the Public Safety Radio Services:

> Frequencies listed in this part will not be assigned exclusively to any one applicant.

In practice, however, frequency assignments have been made on an individual basis and sharing, when it exists, has been a result of informally developed arrangements rather than of a coherent overall policy. Although the applicant is required to submit a letter of recommendation from the frequency advisor for the area, the advisor is a volunteer and may or may not be properly qualified. In addition, the frequency advisor does not have any authority or desire to consider the necessity for the request and he must avoid jurisdictional disputes. In effect, then, all users deal directly with the FCC. There is no hierarchy of organization among users and no overall communications planning that extends beyond the limits of individual police departments. In many cases, the user—a police department—simply contacts a commercial service organization whose representative fills out the required forms and processes them without the leaders of the municipal government being involved.

The FCC assigns frequencies to the local government but for use by a specific service—police, fire, highway maintenance—so that in effect, although not in intent, the local government itself is not involved.

THE PROBLEM OF THE SMALLER COMMUNITIES

Matters of frequency assignments come to the FCC on a piecemeal basis and although the FCC has urged users to consider and present the broader implications of their requests, the actual workings of the system have led to keen competition for ever-scarcer frequencies on a highly individual basis. The result has been that, although users need relief from frequency congestion, there is a significant variation in traffic loading on the police frequencies in all areas, indicating inefficient use of the total resources. Another result has been that the FCC does not get a coherent picture of spectrum usage within an area so that it can properly address the policy questions on a national level with which it must be concerned.

The first set of recommendations developed here are designed, therefore, to encourage pooling of radio frequency resources into efficient communications networks on the part of Public Safety Radio Service users, to reduce the number of applicants who can deal directly with the FCC, and to require municipal governments to take a greater responsibility for the efficient use of the radio spectrum resources under their control.

[24] The majority of the material in this section has been reviewed in draft form by knowledgeable individuals in the Federal Government and in police work. Acknowledgement of such aid is not meant to imply prior endorsement of the material. Organizations from whom such assistance has been received include the Federal Communications Commission, the President's Office of Science and Technology, the President's Office of Telecommunications Management, the Association of Public Safety Communications Officers, the International Association of Chiefs of Police, the police departments of Washington, D.C., Los Angeles, Calif., and Burbank, Calif., and the Public Safety Coordinating Committee.

It is recommended that the FCC limit by rule the size of municipalities, in terms of population and/or land area, which are located in major metropolitan areas with which it will deal directly in regard to frequency assignments in the Public Safety Radio Service.

This limit on municipality size need only be applied in major metropolitan areas since these are the areas where radio spectrum congestion is a problem. Such areas are subject to clear definition by means of census data. To qualify for frequency assignments, smaller municipalities would be required to work together as a group or coordinate with the core city of the area. Such a response is what is desired for it encourages networking without dictating in any way the manner in which that networking should be accomplished on a local level. It is possible that rare cases will exist where a small community cannot enter into such a network. The FCC rule should allow for such exceptions upon the presentation of substantiating evidence.

Because of the many examples that have been found of small communities having lightly loaded channels, it is recommended that the FCC, by rule, establish a policy that municipalities which fit into the category of the previous recommendation be notified that unless they show justifiable cause for exception they must release within 5 years of date of notification any public safety frequencies which have been assigned to them. Note that FCC licenses are issued for periods no longer than 5 years in any case. Thus, this recommendation involves a decision not to renew licenses rather than to revoke existing ones.

This second recommendation is aimed at bringing into coordinated networks those municipalities which have no motivation to do so because of their present satisfactory situations. There is a sufficient number of such communities and sufficient radio spectrum resources are involved to make the recommendation worthwhile. Note, too, that the first and second recommendations are concerned not only with police but with all public safety spectrum assignments.

THE RESPONSIBILITY OF LOCAL GOVERNMENT

It is recommended that, as soon as practicable, the FCC by rule establish a policy of assigning Public Safety Radio Service frequencies only to the local government and not identified by user and not assigned directly to the users such as police or fire departments. It is further recommended that frequency advisory matters be handled by one committee in each area instead of by separate committees for police, fire, highway maintenance, and forestry conservation. These committees should receive the same formal recognition by their State governments as does the committee presently functioning in Michigan.

Radiotelephone traffic loading is not only uneven across the police bands, but is perhaps even more uneven across the entire Public Safety Radio Service bands. Further, there are gross characteristics of the different users which can be utilized for greater overall efficiency. While the fire department frequencies are needed imperatively when they are needed, the traffic loading is often not as heavy on the average nor as evenly distributed in time as is the case for the police. Highway maintenance frequencies are most heavily used during the normal working day. Evenings and weekends, when the police frequency bands are most congested, the highway maintenance bands can be expected to be idle in most cases. Other frequencies such as those used for dispatching schoolbuses are obviously busy certain hours and idle for long periods.

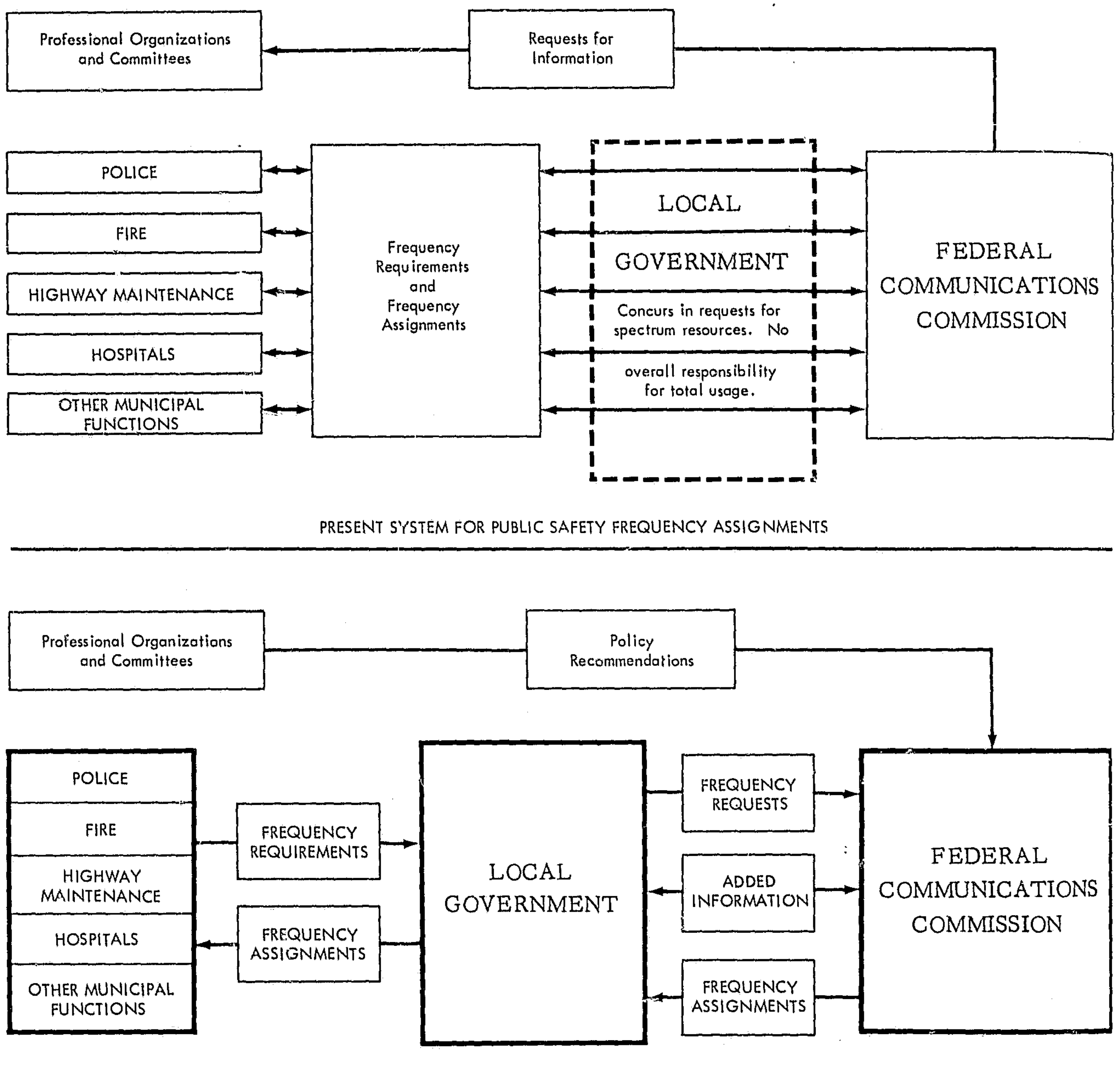
Police communicators do not use these frequency resources of their municipalities because these frequencies are not licensed for police use. The FCC has recognized the need for multiple use of radio frequencies by establishing within the Public Safety Radio Service a band of local government frequencies which can be used for any legitimate local government activity. The majority of the frequencies in the public safety bands are, however, specified for type of user. Secondly, it is not politic for the police to examine the resources of other local government organizations. Thus, a city may have more than adequate total radio spectrum resources to create a highly efficient radiotelephone network and, at the same time, the police may be desperately short of radio resources. It is probable that this is the case in at least one major metropolitan area with serious police communications problems.

The response from one knowledgeable and experienced individual to the suggestion that the subdivisions of the Public Safety Radio Service be eliminated—for those subdivisions which involve municipal radio services—was that possibly such a move would imply the abdication on the part of the FCC of some of its responsibilities. His point was that the FCC is responsible to see that police, fire, and other municipal functions have adequate spectrum resources.

However, it is more properly the function of the city government to see that its people have adequate police and fire protection. The FCC, by breaking down the frequency assignments below the municipal government level, injects itself, to an extent, into local government affairs, increasing the difficulty of its own task and placing artificial restraints upon the municipal government. This was not the case before radio spectrum congestion became a problem. Under the broader characterization of the frequencies involved, the FCC retains its capability to see that there are adequate spectrum resources for municipal functions since individual requests for frequency assignments must still develop the justifiable need. The municipality, however, is responsible for the efficient use of its total radio spectrum resources, and designs based on economies of scale become possible. The proposed change in the assignment procedure is diagramed in figure D–12.

Note that the municipality retains the freedom to develop, in cooperation with neighboring cities, a coordinated police network or its own coordinated public safety network, or any combination of the two. From the FCC

FIGURE D-12. PRESENT AND PROPOSED RELATIONSHIPS BETWEEN THE FCC AND PUBLIC SAFETY AGENCIES



PRESENT SYSTEM FOR PUBLIC SAFETY FREQUENCY ASSIGNMENTS

PROPOSED SYSTEM FOR PUBLIC SAFETY FREQUENCY ASSIGNMENTS

viewpoint, the only requirement should be the efficient use of the limited radio frequency spectrum.

The role of advisory groups shown in figure D–12 should not be overlooked. In the present situation they have provided, and in any new situation will continue to provide, invaluable advice and guidance to the FCC on policy matters that transcend the level of local areas. These groups include:

The International Association of Chiefs of Police (IACP)

The International Association of Fire Chiefs (IAFC)

The International Municipal Signal Association (IMSA)

The Association of Public Safety Communication Officers (APCO)

The Forestry Conservation Communications Association (FCCA)

The American Association of State Highway Officials (AASHO)

The Land Mobile Section of the Electronic Industries Association (EIA)

The Public Safety Communications Council

The Advisory Committee of the FCC for Land Mobile Radio Services

Eastern States Police Radio League (ESPRL)

The contributions from all of these groups has, in spite of the informal nature of an advisory function, often been substantial as evidenced by analyses presented in FCC dockets.

RETENTION BY THE FCC OF RESPONSIBILITY FOR SPECTRUM ASSIGNMENT

Finally, in connection with the frequency assignment procedures, the suggestion has been made on several occasions that the public safety bands be placed in a special category distinct and separate from that of the commercial, industrial, and broadcast users and possibly outside the FCC jurisdiction. The approach has obvious merit in that the criteria for evaluation of the needs in public safety are, and should be, totally different from those used for the needs of the commercial interests. This difference is emphasized by analyses currently being made of the "dollars value per unit wave length" of the spectrum. It is difficult to apply this dollar approach to the public safety users.

In spite of the fact that the public safety users are in a different category than are the commercial and industrial users of the spectrum, the creation of a special category for public safety does not appear to be practicable. The three possibilities are:

Transfer public safety from the nongovernment bands, under the FCC jurisdiction, to the government bands, under IRAC jurisdiction.

Create a new category and a new agency to handle the public safety portion of the spectrum.

Retain the present status but create conditions to improve the "bargaining power" of public safety users vis-a-vis broadcasters and commercial users.

The first possibility does not appear to offer any advantages to the public safety user, and in particular, appears to have several disadvantages. IRAC, (Intergovernmental Radio Advisory Committee) is a committee of Government agencies which operates under the support of the Executive Office, Office of Telecommunications Management. In working with IRAC public safety officials would find themselves immersed in Federal Government activities with which they were not familiar and often discover that essential information on frequencies was classified by the military. There are obviously enormous advantages to working in a completely open atmosphere with the FCC and for this reason the shift to IRAC is not recommended.

The second possibility of a new category and a new agency is also considered to be inadvisable. The creation of a new category and a new agency would further complicate the problem of government administration of spectrum allocations. Considerations of reallocation of spectrum space in the nongovernment bands would involve interactions between two Federal agencies which would inevitably slow the process and make more difficult the decisions.

Accordingly, it is recommended that the public safety bands be retained in the nongovernment portion of the radio spectrum under the jurisdiction of the FCC. This recommendation rejects the suggestion that this band of frequencies be transferred out from under FCC control to the government portion of the spectrum.

Consider now the third possibility, that of retaining the present administrative machinery, making only those changes necessary to improve the relative position of the public safety users.

PROCEDURES FOR DEVELOPMENT OF QUANTITATIVE PROJECTIONS OF NEEDS

With the exception of the Associated Public Safety Communication Officers (APCO), the organizations which provide guidance to the FCC in police communications matters do so from the overall viewpoint of the land-mobile users. Further, industry is well represented in these other organizations which include the Land Mobile Advisory Committee of the FCC and the Land Mobile Section of the Electronics Industries Association. While there is no fundamental objection to industry working in support of public safety—and indeed the technical personnel supplied by industry have made some outstanding contributions—the industry sales base in police communications is small compared to its sales base in commercial and industrial mobile communications.

The only organization, then, that represents the police communications community directly is APCO. APCO, however, is a professional organization composed mainly of public safety communications personnel who pay their own dues to provide operating funds. There are some State, county, and municipal memberships (governmental) in Illinois, Arizona, and California, but for the most part the local governments provide no formal support. While a greatly strengthened FCC field organization would relieve APCO of many of its radio spectrum user coordination responsibilities, such a development would represent outside monitoring rather than voluntary user cooperation and would represent a more expensive and probably less effective means of effecting an FCC user interface. APCO, presuming it can obtain the financial support to carry out the duties involved, is probably the most logical organization to provide the FCC with continued projections of police needs and to guide the police community toward a unified approach to their radio-spectrum problems. In spite of these handicaps, APCO has provided leadership in publicizing to the FCC the communications problems of public safety and the police. The organization supports a Washington-based attorney to represent public safety interests to the FCC. APCO has neither the financial resources nor the personnel, however, to prepare the detailed engineering analysis or economic studies which are so often required to provide effective evidence in FCC dockets. While the service that APCO has been performing has been of unique value and should be encouraged, there is room for further steps to enable the public safety users to effectively present their needs. Accordingly, the following two recommendations are made.

It is recommended that the FCC seek to develop long-range predictions, with justifications, of the communications needs of the police.

It is recommended that the FCC inform the various States and the heads of local governments in the large metropolitan areas that they will, in the future, be expected to provide justification for their radio frequency needs in the form of overall projected public safety requirements for the next decade.

The problem in seeking to provide a single unified spokesman for the public safety community is twofold in nature. On the one hand, there is the division into departments of police, fire, highways, forestry, and conservation which tends to make coordination more difficult. On the other hand, the concept of coordinated public safety activities inevitably carries with it the overtones of excessive governmental control. The recommendations developed here have been made with these considerations in mind.

The projections of police and public safety user needs as made at the national level will necessarily be nationwide in scope. The congestion in the mobile bands is, however, very much a function of geography, being particularly intense in metropolitan areas. Thus, the projected needs derived at the national level should be amplified and detailed by local projections. Further, the existence of a body of documentation detailing the public safety, and in particular the police, requirements will serve to a large extent as a single voice for the public safety community. While the industrial and commercial users of the spectrum will continue to have very vocal representation before the FCC of their interests, the public safety requirements are such that they are very difficult to deny when justified.

ELECTRONICS EQUIPMENT ASSOCIATED WITH THE POLICE CAR

By Raymond Knickel

Contents

INTRODUCTION

Senior police officials, in addition to being concerned about alleviating the spectrum congestion problem expressed a need for a number of new electronic techniques and devices. These new techniques and devices would all in one way or another increase operational effectiveness or decrease costs. In the limited time available, the following were considered and are reported on herein:

- ☐ The potential for equipment standardization to reduce cost and ease maintenance and operations problems.
- ☐ The use of mobile teleprinters in patrol cars to provide officers with written instructions, and to reduce the likelihood of unauthorized interception.
- ☐ The advantages of utilizing microminiaturization techniques to design small personalized two-way radios for police use.
- ☐ The advantages of car-locator devices and the techniques available for implementing car-locator systems.

As the result of the success of AID and the Association of American Railroads in standardizing mobile two-way radio equipment, it appears that a limited standardization program would provide substantial benefits to the police community, and that a limited standardization program could be undertaken immediately. The benefits of a broad standardization program are less certain.

A number of manufacturers have recently developed teleprinters suitable for installation in patrol cars. It appears that their use can do much to relieve the problems of frequency congestion, security, unattended operation, written records and instructions, and the problem of phonetic errors with voice communications. Although some errors in transmission occur when teleprinter equipped patrol cars operate in urban areas while the vehicle is in motion, there are various error-correcting techniques that could be employed. The best means for operationally and technically integrating mobile teleprinters into the police communications system, including the most appropriate error-reducing techniques, still need further study.

Some phrases that are frequently used in police communications have been coded and are widely used to speed communications and increase accuracy. Simple, coded, switch-operated signal devices could be designed to transmit these standard phrases in digital form. The devices could ultimately improve network efficiency and provide direct communication between a police officer and a computer. The potential uses for these coded signal transmitting devices and their probable cost must still be defined.

Presently available hand-held two-way radios for police use are unnecessarily expensive and cumbersome. Microminiaturization techniques could be employed to greatly reduce their size, weight, and cost. Patrol car radios could be converted to radio repeaters for amplifying and relaying messages from small low-powered units carried by the officer when he is away from his car. Contrary to popular belief, there are indications that hand-held units might provide more reliable communications on higher frequencies such as 960 MHz, particularly when trying to communicate from the inside of a building. Because definitive data on this issue is lacking, however, a test program is needed to determine whether further reductions in size and more reliable communication could result from using higher frequencies. The Federal Government should assume the leadership in carrying out this test program, in bringing about the microminiaturization of hand-held two-way radio equipment and in developing methods for the officer away from his car to use his car radio as a repeater.

There is a recognized need by the police community for a means of tracking and plotting the locations of police vehicles. It has long been assumed that for car-locator systems to be effective they would have to be accurate to within about one block. An analysis showed that most of the potential benefit of a car-locator system could be achieved with a system having an accuracy no better than a quarter of a mile, which opens the possibility of using techniques that had been previously considered to be too inaccurate.

A patrol car emitter-callbox sensor technique and a modified radar transponder technique, as well as other possible techniques, appear to warrant further study.

POTENTIAL FOR STANDARDIZATION OF POLICE MOBILE RADIO EQUIPMENT

Equipment is already standardized to a large extent in police radio but only because a few large suppliers dominate the field, as shown in table E–1. Their products become standard for the police department that uses them; replacement units purchased from any other supplier in a later year would be incompatible.

Table E–1.—The Police Mobile Radio Market

	Millions	Percent
Gross sales per annum:	$170	100
Total land mobile radio sales	30	18
Total public safety radio sales	9.8	6
Total police radio sales		
		Percent of total market
Suppliers:		50
Major supplier		30
2d major supplier		10
3d major supplier		10
All other suppliers		

Customers (police):
Approximately 40,000 separate police agencies, the few largest of which purchase perhaps $500,000 of radio equipment per year.

The radio industry [1] tends to argue against standardization beyond the electrical and performance standards provided now by the EIA. These standards cover such topics as:

- Minimum power supply life;
- Average radiated power;
- Amount of spurious radiation;
- Average radiation sensitivity.

The police speak of standardization in terms of ease of use of operating controls, ease of maintenance, and ease of replacing one manufacturer's equipment with that of another.

POTENTIAL ADVANTAGES OF STANDARDIZATION

There are a number of possible ways in which standardizing equipment designs can lead to cost savings:

- ☐ Equipment standardization would allow communities, counties, and even States to combine their equipment procurements so that essentially identical equipment could be bought in large quantities by competitive bid.
- ☐ Less test equipment, and in some instances simpler test equipment, would be required to maintain equipment in repair.
- ☐ A smaller variety and a smaller overall number of spare parts or interchangeable plug-in modules would have to be kept on hand if equipment were standardized. If all the communities within a metropolitan area used identical equipment, economies could be effected by combining their repair facilities.
- ☐ When improvements or modifications to standardized equipment are required, identical modification kits could be procured in large quantities at a lower unit cost by combining the requirements of several police organizations.
- ☐ With only one type of equipment to repair, police radio technicians would require less training.
- ☐ Even limited standardization could enable police departments to avoid becoming "captive customers" of a single supplier because of previously having purchased equipment from that supplier.

POTENTIAL HAZARDS OF STANDARDIZATION

Despite the many genuine advantages of equipment standardization, there are also potential disadvantages. The major manufacturers of police radio equipment object strongly to equipment standardization. They argue that standardization would stifle their incentive and desire to keep improving their product. The manufacturers point out that they spend a great deal of their own funds on research and development with the hope of bettering their equipment in some way which will give them an advantage over their competitors.

Even if standardization were carried out in a very limited sense, such as requiring interchangeability of receivers, transmitters and power supplies, the manufacturers claim that their efforts to develop improvements would gain them no rewarding competitive advantage. They argue that before they could market any new technique, agreement would have to be reached by the purchasers to the effect that the proposed new technique should be made a part of the standardized equipment. The time required to reach such an agreement would give the competitors time to develop similar techniques.

The manufacturers further state that at present they maintain large service organizations which provide much needed advice and assistance to police department technicians. With standardized equipment and large, highly competitive purchases, the manufacturers could not be sure what the amount of their police radio equipment business would be. Consequently, they say that they would have to dissolve or greatly reduce the size and effectiveness of their present service organizations. This, they maintain, would require police departments to spend their own money to improve the quality of their repair service organizations.

[1] "Standardization for Police Communications," brief survey of the problem supplied to Science and Technology Task Force by the Motorola Corp., undated.

The manufacturers also point out that several groups of mobile equipment users have in the past attempted to standardize equipment. They state that these attempts have, for the most part, ended in failure and generally have been abandoned. Cited as examples are the experiences of the Forestry Service and the Military Police.

Although all of the above arguments have counterarguments, it is obvious that standardization must be approached with caution. In the process of standardizing equipment design, means should be found to reward manufacturers that develop improved designs or features. Standard equipment designs should be developed by engineers familiar with the operational requirements of police radio and with the caliber of maintenance personnel available to police radio departments.

Every attempt should be made in adopting standardized equipment to utilize designs that will be as simple and as easy to maintain as possible, thereby lessening dependence on the service organizations of the manufacturers.

The hazards of standardization should not be risked where there is not a clear-cut advantage to standardization. Carrying standardization to the limit where every electrical component and its location is precisely specified could well result in the dire consequences of standardization predicted by the manufacturers. On the other hand, standardization to the point where police departments avoid becoming captive markets would certainly appear to be the minimum that should be considered.

AID SUCCESS IN STANDARDIZING PORTABLE RADIO EQUIPMENT

The Telecommunications Branch of the Office of Public Safety of the Agency for International Development (AID), under the direction of Mr. Paul Katz, has designed a line of special radio transceivers primarily for service in Vietnam. These units have been made standardized units by the AID Office of Public Safety and they are now scheduled for AID public safety programs in Costa Rica, Colombia, Thailand, Laos, and Guatemala. AID estimates that more than $4.5 million had been saved as of 30 March 1966 as a result of adopting these transceivers as standardized units for AID public safety programs throughout the world.

The AID equipment was developed originally because available commercial equipment contained many expensive innovations that added to the weight and cost of the equipment and which were not needed in AID public safety programs. Furthermore, despite the expense and sophistication of the commercially available units, they did not satisfactorily fulfill the requirements of AID. AID required equipment that would be lightweight, capable of being carried on patrols, easily mounted and dismounted on a vehicle, usable as a base or relay station, capable of using regular batteries or house current, and low in cost. The AID design fulfilled these requirements and led to the significant cost savings.

The large cost saving was derived from two aspects of the AID equipment development program. First of all, the equipment, being less sophisticated (e.g., it had no selective signaling capability), cost less to build. Secondly, by standardizing the units and by combining what otherwise would have been a number of relatively small individual procurements, AID was able to make one large competitive bid procurement. The result has been that AID now pays $146 for their hand-held units as compared to $650 to $700 for previously available equipment. Larger detachable mobile units now cost $215, compared to $850 for less versatile units formerly used.

Very little has been sacrificed in the way of quality in the AID design. However, since the units were for use in sparsely populated areas having little industry, the specifications are not as stringent regarding spurious oscillation as would normally be required for equipment to be used in the United States. Furthermore, the equipment does not have provisions for either the coded squelch or selective signaling feature used by many United States police units.

AID, by developing standardized equipment and combining procurement, has managed to provide police radio equipment at approximately one-fourth the cost of comparable nonstandard commercial units. Although the equipment specifications are not as stringent as those of domestic large city police forces, the equipment is of comparable complexity and quality.

PROPOSED STANDARDIZATION PROGRAM

A significant portion of the advantages of standardization could be achieved at a very early date, and with a minimum of effort, through a program of limited standardization. The full benefit of standardization, based on equipment designs incorporating the latest and most modern techniques for enhancing the effectiveness of police communications, might require a broader and lengthier program of standardization.

Limited Standardization Program

The objectives of the limited standardization program should be to standardize equipment to the point that equipment units built by different manufacturers would be operationally compatible, electrically and physically interchangeable, and equipped with identical operating controls. This would include standardization of the following aspects of equipment design:

- Sockets and plugs;
- Terminal strips and the utilization of the individual terminals;
- Housing dimensions;
- Mounting racks and base plates;
- Control heads;
- Technique used for selective signalling;
- Crystals and crystal holders.

The Association of American Railroads has successfully standardized its equipment so that all of its mobile radios are electrically and physically interchangeable. They have accomplished this by standardizing sockets, plugs, terminal strips, housing dimensions, mounting racks, and base plates. The Colorado Highway Patrol has designed a standard control head for its use.[2] Police maintenance departments regularly modify different manufacturers' equipment to make their selective signalling systems compatible. Thus, the proposed limited standardization program has been demonstrated and is feasible.

The program should be conducted in two phases: A study phase and an implementation phase. The study phase should analyze requirements and existing equipment and develop specifications for the aspects being standardized. The implementation phase should include the equipping of demonstration patrol car installations, the publicizing of the limited standardization program results, and distribution of limited standardization specifications. The patrol car mockup should include a standardized control head and modified conventional police radios.

Broad Standardization Program

The objectives of the broad standardization program would be to develop, over a period of time, a line of standard police radio equipment which would provide police with useful and reliable communications at low cost.

The equipment should be designed to incorporate advanced features as they become available and are needed by individual departments. In order to keep the equipment cost at a minimum, any unnecessary features should be eliminated from the basic design. In addition, there would have to be wide acceptance of the equipment so that it could be built in large quantity lots.

Any such standardization program must be continuously reviewed in order that police radios keep pace with technological advances. The initial program definition should seek to determine the extent to which standardization is feasible and to outline a program for achieving whatever degree of standardization is found desirable. The study should address itself to questions such as:

- ☐ How many different standardized transceiver models would be required to meet the needs of cities of different sizes as well as county and State patrol cars?
- ☐ What aspects of equipment design (in addition to those in the limited standardization program) could quickly and easily be standardized?
- ☐ What features should the standardized equipment design have in order to accommodate possible future innovations such as car locators, mobile teletype, spectrum conserving modulation schemes, car radio repeaters for patrolmen away from their car, and scramblers?
- ☐ What effect will microminiaturization and integrated circuitry have on the standardization program?
- ☐ Should multichannel equipment design use the channel switching technique of present day police equipment or should it use a technique similar to the automatic idle channel search of the Bell Telephone car radio systems?
- ☐ Should standardization be accomplished by developing a completely standardized line of equipments, or should individual submodules be standardized?
- ☐ How can a continuing innovative interest by manufacturers be ensured?
- ☐ How should the trend toward integrated community wide police communication nets be reflected in the standardized designs?

DIGITAL COMMUNICATIONS IN THE POLICE MOBILE RADIO NETWORK

Although voice is an indispensable mode of communications for patrol vehicles, it has a number of problems:

It is very wasteful of the already overcrowded radio frequency spectrum;
It provides no protection against unauthorized interception of official police communictaions unless expensive scramblers are employed;
It does not provide a set of written instructions or a written record;
It is subject to phonetic errors;
It cannot be received by an unattended patrol car without special recording equipment.

Digital communications links that would augment the existing voice communication links could do much to alleviate these problems. Such digital links could be teleprinter links or coded signal device links, either of which could be one-way or two-way.

TELEPRINTER LINKS

In addition to meeting some of the problems of voice communications, two-way teleprinter links could connect a patrolman in a car directly to a computer so that he could check for wanted persons or stolen autos.

A receive-only teleprinter in the patrol car would be much less expensive. Its main shortcoming would be its inability to address a computer directly. However, when the operational problems in having an officer typing out messages in a patrol car are considered, this shortcoming loses some of its significance.

Most of the routine all-points communications traffic could be placed over a receive-only teleprinter link. A large percentage of police communications is of this character, e.g., stolen car lists, report notices, and wants. Transmitting this information routinely over a narrowband teleprinter channel frees the wider band voice channel for more urgent communications, such as those concerning crimes in progress, pursuits, and so on.

[2] Niblack, D. L., "New Concepts in Mobile Control Console Design," The APCO Bulletin, vol. 32, No. 9, September 1966.

Teleprinter or digital data communications are inherently more secure than voice, even without special encryption or scrambling. Monitoring of police communications frequencies would become less productive to the criminal. Should criminals reach a new level of sophistication where even digital transmissions are detected and utilized, codes can be changed periodically by relatively simple and inexpensive schemes in order to maintain a high level of short-term security.

With only minor changes to the law in many States, a radioteleprinter record can serve as a legal warrant of arrest, search, or seizure. For example, sections 850 and 851 of the California Penal Code read as follows:

> 850. A telegraphic copy of a warrant or an abstract of a warrant may be sent by telegraph or teletype to one or more peace officers, and such copy or abstract is as effectual in the hands of any officer, and he must proceed in the same manner under it as though he held the original warrant issued by a magistrate. An abstract of the warrant as herein referred to shall contain the following information: The charge, the court of issuance, the subject's name, address and description, the bail, the name of the issuing magistrate, whether the offense charged is a felony or misdemeanor, and the warrant number.
>
> 851. Every officer causing telegraphic copies or abstracts of warrants to be sent, must certify as correct, and file in the telegraphic office from which such copies are sent, a copy of the warrant and must return the original with a statement of his action thereunder.

There are at least four manufacturers that have built teleprinter receive-only units for mobile use. The installed cost of the units is estimated to range from about $1,000–$2,000.

In order to provide a two-way digital link, an encoder unit, in addition to the teleprinter receiver, would have to be installed in the patrol car. Encoder units for transmitting teletype from the car would cost from about $2,000 to $4,000. Two-way teleprinter links with patrol cars can be expected, therefore, to cost somewhere between $3,000 and $6,000 per car, including required modifications to the patrol car radio equipment.

The signals required to operate a teleprinter machine consist of a sequence of current and no-current pulses, known as "mark" and "space". Before these d.c. teleprinter signals can be transmitted over standard voice frequency communication channels, they must be converted to a.c. tone signals. This can be accomplished by one of two methods. The first method consists of keying a tone-oscillator On and Off, with presence or lack of a tone being used to indicate a mark or a space. The second method, known as frequency-shift keying (FSK), is to have the tone oscillator shift to a different tone or frequency whenever it is keyed, the presence of one frequency indicating a space and presence of the second frequency indicating a mark.

Regardless whether FSK or On-Off keying is used, the total bandwidth required to transmit telegraph at 100 words per minute is in the order of 120 to 170 Hz.

The average police radio transmission link can accommodate a bandwidth of at least 3,000 Hz. All that is required for intelligible speech is 2,400 Hz. Therefore, through the use of filters, it is easily possible to add two teletype channels within the 3,000 Hz voice channel of existing police networks. If it were completely devoted to teletype, one voice channel could accommodate 16 teletype channels. Figure E–1 is a block diagram of how a teleprinter link might be instrumented.

Although preliminary tests have been encouraging, there have been no conclusive tests as to the feasibility of operating mobile teleprinter links at the more commonly used police radio frequencies in the vicinity of 150 and 450 MHz. Propagation in built-up areas at these frequencies is known to take place by reflection and scattering of the radio waves as they bounce off buildings and other reflecting objects. As a result, the signal received at any point is actually the sum of several signals arriving via different paths. If the signals from the different paths all arrive in phase, the combined signal will be very strong. If all of the signals from the different paths are completely out of phase, the resulting combined signal will be lost in the noise. Moving the antenna a fraction of a wave length, in this case only a few inches or a foot or two, can completely change the phase relationships of the arriving signals making the resulting signal either much stronger or weaker.

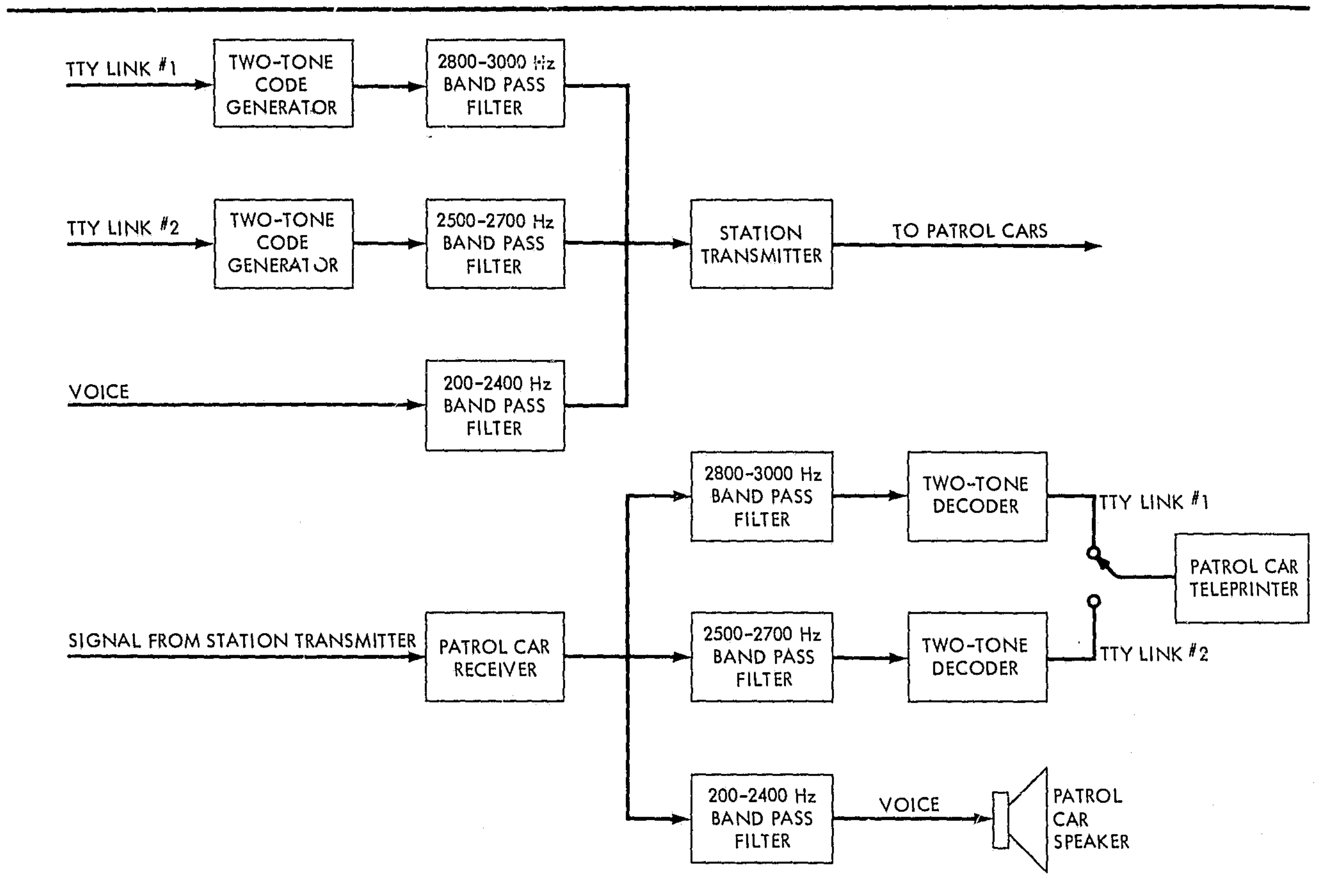
Thus, the signal strength at the antenna of a car in motion will be continually varying. With frequency modulation, which is universally employed by police units, these constant excursions in received signal strength are generally noticed only when the signal drops so low that it cannot be detected. Even then, since this situation is usually only momentary, in voice communications only a part of a word is lost and the meaning is still conveyed. During the momentary signal fade, the patrol car receiver emits a short burst of noise. Any data link, teleprinter, or coded signal device would respond to this noise and print some character that will almost always be in error.

Since teleprinters for mobile use have only recently become available, there is insufficient data available to determine the extent of the problem of signal dropout errors. The only test results available merely confirm that there will be errors. During "Operation Corral" conducted by the New York City Police Department, teleprinters were installed in patrol cars. A transmission link operating at 155.70 MHz was used during the experiment. A number of errors were noted when the patrol cars were in motion, but no data are available on the error rate.

There are techniques, both operational and technical, for reducing the error rate. One operational technique would be to send each character or message twice. Error correcting codes could also be used to reduce the error rate.

Although it would add to the cost, the technique of space diversity reception could reduce the error rate significantly. This technique depends on the fact that if one antenna is in a signal null, it is very improbable that a second antenna placed a few feet away will also be in a signal null at the same time. Therefore, by using two

FIGURE E-1. POSSIBLE INSTRUMENTATION OF TELEPRINTER LINKS



spaced antennas and by duplicating portions of the patrol car receiver, it is possible to combine the signals of the two antennas in such a way that if either antenna is receiving a usable signal, the teleprinter records the correct character. Error would result only during those rare occasions when both antennas are simultaneously in a null. The cost of implementing this technique is estimated to be in the order of $300 to $500 per car. The related technique of frequency diversity, which uses two frequencies for each link, could also be employed.

CODED SIGNAL DEVICES

Much police communication with patrol cars is very stereotyped. Consequently, many standard phrases have been given numerical codes in order to speed communications, to increase the accuracy of communications, and to provide some minimum degree of communication security. It is possible to use digital techniques to transmit these coded phrases. This would speed the rate of transmission still further and at the same time add a significant degree of security to communications. Since only about 100 different coded messages or phrases are used,[3] the bandwidth required would be very small. As with teleprinter links, it would be possible to add such a coded signal link to an existing voice channel link without noticeable degradation of the voice quality. The technique employed would be similar to that shown in figure E–1 for teleprinter links. In this case, however, instead of a teleprinter device typing out the message, some sort of a display device would be used.

Coded signal transmitting devices for field units are technically feasible. These units could improve network efficiency by forwarding such information as availability (e.g., out-of-service, occupied but available for priority assignments, available), using the "10-series" of codes of the "APCO Public Safety Communications Procedure Manual." More complex units could permit communication between a police officer and a computer.

There is little information available upon which to base cost estimates for transmit type coded signal devices for vehicle use. If the number of coded signals were kept to about two or three, the device could easily be incorporated into car-locator systems when they become available. More complicated equipment capable of direct

[3] Associated Public Safety Communications Officers, Inc., "APCO Public Safety Communications Procedure Manual."

access to a computer could be expected to cost as much as several thousand dollars.

Coded signal receiving devices, while technically feasible, are operationally limited. Without a full alphanumeric display, they cannot display names, addresses, or other information commonly transmitted over police radio circuits. Communications would be confined to those items in the code book.

Cost estimates furnished by one manufacturer which builds signaling devices and a mobile teleprinter indicate that the mass-produced teleprinter is comparable in cost with the specialized signaling unit. A specialized receive-only signaling system would be cheaper than a teleprinter link only if teleprinters are produced in very small quantities. A specialized signaling system probably is limited primarily to police users, who represent but a small percentage of the total vehicular communications market to which teleprinters could be sold.[4] A mobile teleprinter has very broad use across many markets and is more likely to be mass produced.

CONCLUSIONS

Both teleprinter and coded signal device links with patrol cars are technically feasible. Although two-way teleprinter links are probably too expensive for general use at this time, there may be specific applications that would warrant their cost.

Receive-only coded signal devices for vehicles would cost almost as much as a counterpart teleprinter link, and their utility would be so limited by comparison that their use would not seem to be warranted.

Patrol car receive-only teleprinter links would cost between $1,000 and $2,000 per car, depending on the elaborateness of the equipment (for instance, strip printers or page printers) and the extent to which it is found necessary to implement error correcting techniques. The advantages to be gained through the use of patrol car receive-only teleprinters warrants their consideration for general use.

An operational evaluation should be undertaken to assess the advantage of mobile teleprinters for police operations. If these are found to be significant, then a system design program would be needed to:

- ☐ Examine how mobile teleprinters can best be integrated into existing police voice communications systems.
- ☐ Determine through analysis and test the magnitude of the error rate problem in high multipath areas.
- ☐ Make a comparative evaluation of alternative error reducing techniques.
- ☐ Evaluate alternative methods for multiplexing teleprinter links within voice channels.
- ☐ Prepare equipment and system specifications.

SMALL PERSONALIZED RADIOS FOR POLICE USE

STATEMENT OF THE PROBLEM

Police contacted during this study were unanimous in expressing a need for a small, inexpensive, lightweight two-way radio for the officer on foot so that his actions can be coordinated through the appropriate headquarters. The car radio is useful to the mortorized patrolman only when he is in the car.

Regardless of his environment, an officer needs his communication link to report incidents, to call for help, or to request instructions. For instance, he may be inside a building, he may be patrolling a beat in the center of a city, or he may be patrolling a tree-lined street in the suburbs. He must be able to operate this link even if he is engaged in a gun battle, has an unruly suspect in tow, or is in the midst of a riot.

Portable equipment available today does not satisfactorily fulfill this urgent need. It is too heavy, too bulky, too expensive, too awkward to operate, and does not provide reliable communications from the inside of buildings. Even though existing transistorized units weigh only 2 to 3 pounds, this is a burden when added to the other equipment that an officer must carry.

Furthermore, existing units are awkward to operate in emergency situations, primarily because the officer must pull out the antenna and hold the unit so that the antenna is away from his body. Shirt sleeve, trouser leg, and earphone cord antennas have been developed, but they are very inefficient because of body shadow loss.

Also, existing units for the officer on foot are too costly. The average unit with attachments generally costs from $500 to $750. Most police departments are not willing to pay this high a price even if they are willing to put up with the size and weight of the units.

It would appear that existing technology can provide a partial, if not a complete, solution to this problem of portable radios for foot patrolmen. The technology of microelectronics employing integrated circuits can greatly reduce the size and cost of units.

POTENTIAL FOR THE APPLICATION OF MICROELECTRONICS

Microelectronics is already revolutionizing many sectors of the electronics industry. Microelectronics, through the use of integrated circuits, can dramatically reduce the size and weight of electronic equipment. At the same time, this miniaturization results in increased reliability. Perhaps the most significant advantage of these new circuits, however, is that they can be produced cheaply.

Leading microelectronics manufacturers agreed that microminiaturized versions of currently used police units would weigh about 12 oz. and could be manufactured at a cost of about $150 in lots of 20,000 or more. This would represent a reduction in cost by about four-fifths

[4] There were 205,872 mobile transmitters in the police service out of 4,765,722 mobile transmitters in the total category of Safety and Special Radio Services at the end of fiscal year 1965 (31st Annual Report of FCC for fiscal year 1965, p. 146).

and a reduction in weight by about two-thirds. Possible size, weight, and power characteristics of a microminiaturized version of present day equipment would be as follows:

Radio frequency power output	2 watts.
Audio power output	75 milliwatts.
Transmitter efficiency of power consumption	$\geqq$ 50 percent.
Battery weight	$\leqq$ 0.33 lbs.
Total weight	$\leqq$ 0.75 lbs.
Cost per unit (in quantities of 20,000 or more)	$\leqq$ $150.

CHOICE OF OPTIMUM FREQUENCY

One of the first steps in the design of portable radio systems would be to compare radio link performance at the different frequencies that either are now available or could be made available to the police in the future. For example, operation at higher frequencies might mean less efficient transmitters, more efficient transmitting and receiving antennas, better building penetration, greater foliage loss, decreased receiver sensitivity, and less competition with industrial electrical noise. The combined net effect could be favorable or unfavorable. There are some indications that if small personalized two-way radios were operated at higher frequencies, such as 960 MHz, there might be a net improvement over the presently used lower frequencies, especially when trying to communicate from inside buildings. Motorola Corp. reported in an in-house paper [5] as follows:

> One effect noted in making our urban area tests was the ability of the 900 mc signals to penetrate into tunnels. Comparison tests with 160 mc signals showed that certain viaducts would attenuate 160 mc signals almost completely 100–200 feet inside the tunnel while the 900 mc signals provided satisfactory performance 400 to 500 feet inside the viaduct. Actually the viaduct was only about 1,000 feet long and it was not possible to get more than 500 feet from an entrance.

Another Motorola in-house report [6] on this same series of tests reported successful communications at 960 MHz from a test vehicle parked 40 feet underground in a parking garage. Bell Telephone Laboratories found in a series of tests run in 1952 [7] that 900 MHz is to be favored somewhat for mobile communications over 150 MHz from a transmission standpoint if full use is made of the possible antenna gain. In comparing the building penetration capability of 35 MHz and 150 MHz, Bell Telephone Laboratories found that the expected range of coverage into buildings is somewhat greater at 150 MHz than at 35 MHz.[8] Police and others consistently report better operational results from within buildings at 450 MHz than at 150 MHz.

These results could be explained by theorizing that the windows and other apertures of buildings, being large in comparison to the shorter wave lengths, become more transparent and that the hallways of buildings act as ducts for the radio frequency energy much as a wave guide operates above cutoff.

Unfortunately, there is no thoroughly collected data on the extent to which the higher frequencies outperform the lower frequencies with regard to building penetration. If experimental results verify that building penetration at the higher frequencies is substantially better than at the lower frequencies, it should be possible to design equipment which would be much less awkward to operate in emergency situations and would provide much more reliable communications from inside buildings. More efficient operation at the higher frequencies could result in further reductions in battery size and cost over that achieved by microminiaturization alone. With microminiaturized equipment, battery weight and cost represent a large portion (perhaps in the order of 40 percent) of the weight and cost of the entire unit.

There are reasons other than improved building penetration why the higher frequencies might be superior. For ease of operation, the equipment should be capable of being "worn" on the officer instead of being handheld. At 150 or 450 MHz, some sort of trouser leg or microphone cord antenna is required, resulting in about 8 or 9 db body shadow loss. In addition, at 150 MHz, because there is no effective ground plane and the antennas do not even approach a quarter wavelength, the antennas are 8 to 15 db less efficient than a dipole antenna. At 450 MHz such antennas come within 2 or 3 db of regular dipole performance.

At a frequency of 1000 MHz, a quarter-wave dipole antenna would be only 7.5 cm., about 3 inches, long. The antenna could easily be worn on the shoulder or the top of a policeman's helmet with a small metal plate as a ground plane. Such an antenna could have a performance at least equal to a simple dipole and it probably would be possible to provide some gain in the horizontal plane, yielding another 1 or 2 db of improvement.

Therefore, by having a more efficient antenna and avoiding body shadow loss, it appears that antennas at 1000 MHz could be made 17 to 26 db better than current 150 MHz body-worn antennas, and 11 to 14 db better than current 450 MHz body-worn antennas. Table E–2 summarizes how some of these performance factors vary with frequency.

A factor militating against higher frequencies is that foilage loss tends to increase with frequency. There could well be other factors that would militate either for or against going to higher frequencies.

To resolve this frequency question, test data must be collected. The test program required to gather the necessary data would be similar to those conducted by L. P. Rice in 1959 [9] and by W. Rae Young in 1952,[10] but expanded to cover the frequency range to 3000 MHz and to include use within buildings.

Since building penetration would vary from building to building, and between locations within buildings, a large number of readings would have to be taken to provide a good statistical data base. Signal strength readings would have to be taken in several typical buildings and at several locations in each of the buildings. These would have to be repeated on about five different frequencies between 150 MHz and 3000 MHz. Signal strength

[5] C. J. Schultz, "Is 960 Mc Suitable for Mobile Operations"; Motorola Corp.
[6] C. J. Schultz, Motorola in-house report, undated, titled "900 Mc, a Vehicular Survey."
[7] W. Rae Young, Jr., "Comparison of Mobile Radio Transmission at 150, 450, 900, and 3700 Mc"; Bell System Technical Journal; November 1952; pp. 1068—1085.
[8] L. P. Rice, "Radio Transmission into Buildings at 35 and 150 Mc." *Bell System Technical Journal*, January 1959.
[9] L. P. Rice, op. cit.
[10] W. Rae Young, Jr., *op. cit.*

Table E–2.—Performance Factors vs. Frequency of Portable Police Radio Equipment

Frequency	Body-worn antenna		Industrial and man-made noise	Foliage loss	Building penetration ability
	Gain with respect to a half-wave dipole	Body shadow loss			
150 MHz	−8 to −15 db	−8 to −9 db (trouser leg or earphone cord)	Appreciable	Uncertain	Uncertain.
450 MHz	−2 to −3 db	−8 to −9 db (trouser leg or earphone cord)	Less than at 150 MHz	More than at 150 MHz	Known to be better than at 150 MHz.
960 MHz	~0 to +1 db	~0 db (head or shoulder antenna)	Less than at 450 MHz	More than at 450 MHz	Indications of being better than at 450 MHz.
2000 MHz	~0 to +3 db	~0 db (head or shoulder antenna)	Probably less than at 960 MHz	More than at 960 MHz	Uncertain.

versus range should be determined by taking measurements over about 20 different distances, varying from a few tens of feet out to about 15 miles.

Other steps that could be taken in approaching the design of portable radios for officers on foot would depend on whether the units were to be used by foot patrolmen or by motorized patrolmen while away from their vehicle. These two cases will therefore be treated separately.

COMMUNICATIONS FOR THE POLICE OFFICER AWAY FROM HIS VEHICLE

Since a motorized officer is almost always within a few hundred feet of his patrol car, its relatively reliable communications set suggests that his portable radio take advantage of the communications available in the car. Possible means of accomplishing this are as follows:

- ☐ Having the car radio detachable so that the officer can carry it with him.
- ☐ Having the car receiver unit detachable and providing the officer with a short-range transmitter, the signal from which would be rebroadcast by the car's transmitter.
- ☐ Developing a simplified transceiver to communicate with a like unit in the car that would be connected to the car's two-way radio for rebroadcasting.
- ☐ Having a car radio capable of being switched to a simple repeater mode and providing the officer with a transceiver operating on base-station frequencies.
- ☐ Developing a simple short-range signaling device that could signal the car and trigger an automatic call for help.

The Single Frequency Repeater Problem

The above techniques, except for the first and the last, would use the patrol car radio as some form of a radio repeater, with the car receiver audio output switched into the car transmitter microphone input. This requires that the repeater's transmitter operate on a different frequency from the repeater's receiver in order that the transmitter signal not block the receiver. However, many police radio networks operate in a simplex mode in which each car's transmitter and receiver do operate at the same frequency. Furthermore, the car radio units are usually designed so that switching of receiver and transmitter frequency is performed simultaneously with the turning of one switch so that the transmitter and the receiver automatically stay tuned to the same frequency. There are three possible techniques for coping with this problem:

- ☐ Use fairly complicated time sharing and signal sampling techniques to switch the receiver and transmitter portions of the repeater alternately on and off at an ultrasonic rate, thereby permitting single frequency repeater operation.
- ☐ Have police networks operate in a duplex mode.
- ☐ Modify two-way car radios so that the frequency of receiver and transmitter portions can be switched separately.

The first technique would be too expensive. The second technique would be wasteful of radio spectrum and may introduce the operational disadvantage of hindering car-to-car communications. The third appears relatively easy to accomplish; it does require extra frequencies linking the car and the patrolman, but acquiring frequencies for such short-range use with low power should not be a serious problem.

Detachable Car Radio

The concept of a detachable car radio has the obvious appeal that it requires no additional frequencies and it avoids the single frequency repeater problem. The only additional equipment would be a portable antenna and a snap-on battery power supply.

There are, however, serious disadvantages in this technique:

- ☐ Even with fully transistorized mobile transceivers, the set would be cumbersome in size and weight.
- ☐ The detached unit probably could not include the final amplifier on the car transmitter and it would, therefore, be a comparatively low power unit.
- ☐ If the car transceiver is operating at a frequency that is less than optimum for transmission from within buildings, communications reliability would be unduly impaired.

Detachable Car Receiver

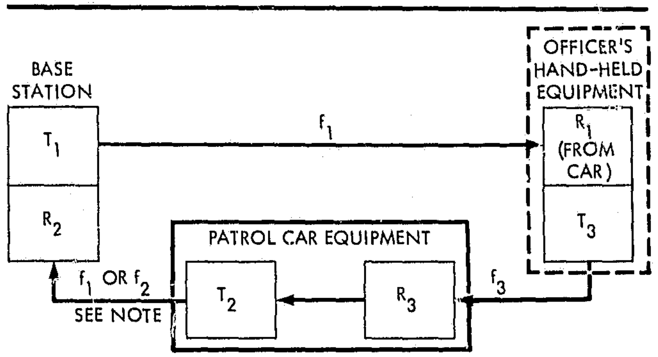
This approach is diagramed in figure E–2. The regular car radio receiver operating at frequency f_1 would be detached and serve as the receiver unit to be carried by the officer. It would be powered by a snap-on battery pack. The officer would also be supplied with a small, inexpensive, short-range transmitter (T_3) to transmit to a small receiver (R_3) installed in the car. The output of receiver R_3 would feed into the regular car transmitter for retransmission to the base station.

Although this method requires an additional hand-held transmitter and an additional receiver unit for the car, it is presumed that units could be developed for this purpose that would be relatively simple and inexpensive. This is because the T_3 to R_3 link (fig. E–2) would always be very short and could be at whatever band of frequencies is found to be optimum for communicating from within buildings. This would mean that the transmitter T_3 could have very low power output and the receiver R_3 could be relatively insensitive. The advantages and disadvantages are compared in table E–3.

As an alternative, the officer could be provided with only the transmit capability, T_3 in figure E–2, and a call to him on the radio could be signaled by remotely sounding the horn or siren of his car.

The possible problem of "active multipath intermodulation" warrants some consideration. It is conceivable that two or more patrol cars in range of a patrolman's hand-held units might have their radio equipment switched into a repeater mode. Even though the transmitters are crystal controlled and presumably operating on the same frequency, they would almost certainly be separated in frequency by several cycles. Reception of two signals of about equal intensity separated in frequency by only several cycles would result in severe intermodulation and probable loss of intelligibility. It may be possible to handle this problem by means of operating circuit discipline, or if further analysis shows that this is not sufficient, selective coding techniques can be employed so that the hand-held unit would turn on only the one repeater as intended.

FIGURE E-2. CONFIGURATION FOR DETACHABLE CAR RECEIVER METHOD



NOTE:
If T_2 is to operate on f_1 (the same frequency as R_1), then circuitry must be provided so that R_1 is muted when T_3 transmits and so that the unsquelching of R_3 turns on T_2.

Table E–3.—Evaluation of Detachable Receiver Approach

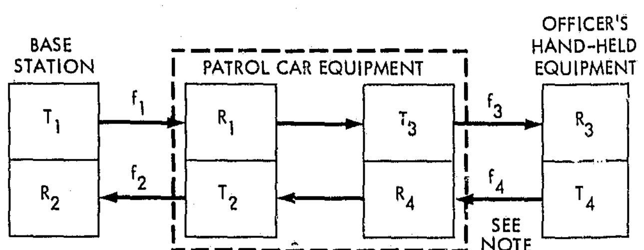
Advantages	Shortcomings
Provides the officer away from his car with the use of the high-powered transmitter in his patrol car.	Requires assignment of an extra frequency for the officer to patrol car link.
Officer-to-patrol-car link can operate in optimum frequency band.	Requires an extra transmitter and extra receiver even though they may be relatively inexpensive.
Takes advantage of patrol car receiver.	Officer's hand-held receiver must operate on the base-station frequency, which may not be an optimum frequency for communication to the inside of buildings.
Can utilize relatively low power hand-held transmitter.	A snap-on powerpack and antenna must be attached to the car radio receiver when removed from the car.
Car receiver (R_3) can be relatively inexpensive, insensitive receiver.	May require the use of selective coding techniques to avoid the "active multipath intermodulation" problem.
Car receiver (R_3) would operate on a different frequency than the car transmitter thereby automatically solving the single frequency repeater problem.	

Simplified Transceiver

Another technique is pictured in figure E–3. This method would theoretically provide the most reliable communications since equipment in the car would be used as a repeater for both outgoing and incoming transmissions. This method would involve providing the patrolman with a small inexpensive transceiver and installing a similar unit in the car, which would be connected to the car's regular car two-way radio as shown in figure E–3.

Compared to the previous concept, this mode avoids engaging and disengaging the regular car receiver and the portable powerpack. It would normally require two additional frequencies for the officer-to-car link unless special circuitry were used that would enable operation with one additional frequency. The regular two-way car radio would have to have an additional transceiver capable of linking up with the portable transceiver. This method may also require the use of selective coding techniques to avoid the "active multipath intermodulation" problem.

FIGURE E-3. CONFIGURATION FOR SIMPLIFIED TRANSCEIVER TECHNIQUE



NOTE:
f_3 and f_4 could be the same frequency if special electronic circuitry is employed to operate this link in a simplex mode.

Car Radio Converted to a Simple Repeater

For radio networks operating in a duplex mode, the output of the car receiver could be connected to the transmitter microphone jack, thereby converting the two-way car radio into a simple repeater. (See fig. E–4.) The officer would be provided with a small, short-range, inexpensive transceiver which would use the same receiving and transmitting frequencies as the base station. This method would not work with simplex communication networks where both receiver and transmitter frequencies are the same.

With this method, every transmission by the base station, as well as every transmission by the patrolman, would be retransmitted by the car radio on its regular transmitter frequency. No additional frequencies would have to be assigned. The only additional equipment required would be a relatively low power hand-held transceiver to be carried by the officer.

Use of Simple Short-Range Signalling Devices

For distress calls, the officer away from his car could be provided with a very simple low powered transmitter (T_3). When the officer presses a button, the transmitter would send a coded signal to the companion receiver (R_3) in the patrol car (fig. E–5). Upon receiving a signal of the proper code from T_3, the patrol car receiver (R_3) would activate a switch that would cause the patrol car transmitter to broadcast an automatic call for assistance. This has the clear advantage that the very narrow bandwidth of the radio control link signal permits a design that could greatly increase the sensitivity of the control link receiver, and thus the link could operate with a very low power hand-held transmitter. It has the obvious disadvantage that the officer cannot describe his predicament and cannot receive an acknowledgement that this call has been received. The dispatcher must rely on a previously reported location. Although expected to be inexpensive, the radio control link would require an additional hand-held transmitter and an additional receiver in the car.

FIGURE E-4. CONFIGURATION FOR THE CAR RADIO CONVERTED TO A SIMPLE REPEATER

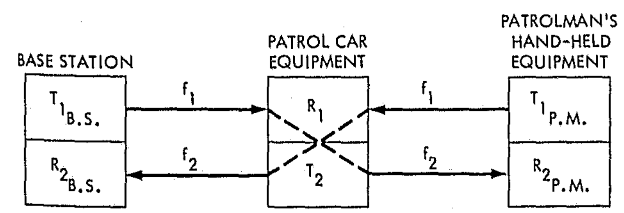
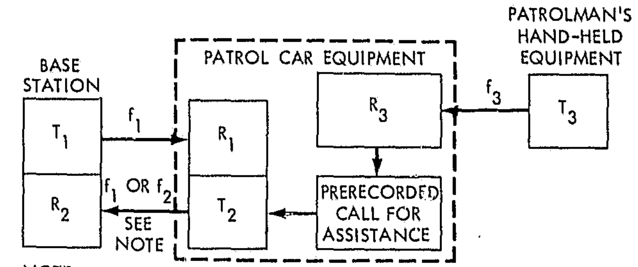


FIGURE E-5. CONFIGURATION FOR SHORT-RANGE SIGNALING DEVICE METHOD



NOTE:
Since the car radio receiver would not be used at all, or only for selective signaling purposes when T_2 would not be transmitting, T_2 could operate on the same frequency as f_1.

Use of Fixed Repeaters

Although all of the methods for utilizing the patrol car radio as a repeater would greatly improve the communications available to the patrolman away from the car, the methods all share some important disadvantages:

All methods require at least some modification to the patrol car radio.

In high multipath areas such as in downtown areas, there are numerous "dead spots"; furthermore the location of these dead spots can change when nearby vehicles are moved. Therefore, there is a possibility that a patrol car may be ineffective as a repeater because it was inadvertently parked in a dead spot.

Because of the low height of the patrol car antenna, it is not an ideal repeater.

The above disadvantages raise the possibility that other methods may be superior to using the car radio as a repeater. These would include the possibility of a hand-held transceiver linking the patrolmen directly to headquarters or to strategically located fixed repeaters. It would not be practical to communicate directly to headquarters in large cities where the patrolman might be inside a building that is several miles from headquarters. On the other hand, smaller cities may find this method both practical and economical, as exemplified by the experience of Berkeley, Calif.

The use of fixed repeaters would be particularly practical in cities such as Washington, D.C., which have already installed a system of repeaters for their foot patrolmen, who are equipped with hand-held transceivers.

Conclusions

There are a number of methods by which the officer away from his patrol car could be provided with relatively reliable communications by using the patrol car radio as a repeater station. Virtually all such methods require the assignment of additional frequencies and some modification of the patrol car equipment. Each of the methods must still be evaluated in terms of performance and cost, both of which depend on the extent to which microminiaturization and integrated circuitry can reduce the size, weight, and cost of the officer's hand-held equipment.

Once the frequency tests discussed previously are conducted, it will be possible to prepare equipment performance specifications for various situations. These could then lead to a development and production program providing microminiaturized hand-held units for less than $150.

COMMUNICATIONS FOR THE FOOT PATROLMAN

The approach to a design of a portable radio transceiver for foot patrolmen would be very similiar to that discussed above. There are, however, important differences. The foot patrolman's equipment has to communicate over a greater range since he does not have a nearby vehicle whose radio could serve as a repeater. Although foot patrolmen have a genuine need to be able to communicate from the inside of buildings, they do not have the need on as many occasions as does the motorized patrolman. In short, compared to the motorized patrolman, the foot patrolman is more interested in range of communications and slightly less interested in being able to communicate from the inside of buildings.

Although the foot patrolman most likely cannot take advantage of a nearby car radio repeater, fixed station repeaters can be located at frequent intervals throughout a city so as to reduce the power and range requirements of the portable radio. This, in turn, reduces the size, weight, and cost of the units.

There is a tradeoff to be made between the number of repeaters installed and the radio frequency power output requirement of the handheld transceiver. Practically speaking, there would be little advantage in reducing power output requirements below 100 milliwatts because at that point the microphone, speaker, case, and antenna become dominant size and weight factors. Regardless of the extent to which the transceiver is miniaturized, the battery becomes unduly heavy and cumbersome in units above about 2 watts of power output.

Determining the number of repeaters to be used would appear to be a matter of making a simple cost comparison to find the point between 100 milliwatts and 2 watts where the cost of the system (repeaters plus transceivers) becomes the lowest. To accomplish this tradeoff analysis, it is necessary to have more factual data on the optimum frequency to be used and on how signal strength varies with range in the communications environment of a police officer.

The theoretical line-of-sight range can be shown not to be a limiting factor in the communications range of a typical portable police radio transceiver. For example, a typical unit would operate at 150 MHz and have 1 watt of power output. It would transmit to a receiver having a sensitivity of 1 microvolt. Under these circumstances, the freespace range of communications is over 1,100 miles.

Considering that police often have difficulty transmitting more than a few blocks, it is obvious that factors other than transmitter power output and receiver sensitivity are primarily responsible for limiting the range of communications at these frequencies. Even if we assume that the line-of-sight horizon limits the range of communications, that a portable transceiver is held at a height of 6 feet above the ground, and that it is transmitting to a base station with an antenna height of 50 feet, the horizon-limited line-of-sight range is 13.5 miles.

In actual practice, even a range of 13.5 miles would seldom be achieved with a portable police unit. The reason is that foot patrolmen are normally trying to communicate in an environment where the line-of-sight path from their transceiver to the receiving unit is blocked by buildings, hills, towers, trees, etc. Communications between the two units is possible then only by virtue of scattering and reflections from these obstacles.

This serves to emphasize the need for performing a statistical analysis of actual field measurements to provide the data necessary for a realistic prediction of useful ranges for hand held transceivers.

In order to develop performance specifications for foot patrolmen radios and for the design of city networks, field data will be needed on reliable communication range as a function of frequency and power output and on the costs of transceivers and repeaters.

Design of radio systems for the foot patrolmen should be related to the handheld equipment for use by officers away from their cars. If the method selected turns out to be that of providing the officer with a hand-held transceiver, then it would be advisable to combine the two specifications. It might be advisable, however, to have two versions of the same equipment: The unit for motorized partolmen might have a low power output, and the one for the foot patrolman higher power.

If the performance specifications for the two types of units are similar, their developments should be combined. If the two units are considerably different, two separate development programs might be needed.

To bring this about, the Federal Government could initiate a survey to determine the size of the immediate market and also the technical specifications which the product should satisfy in order to qualify for the market. The results of the survey could then be made available to industry in the expectation that the competitive process would bring about the remainder of the development.

The Federal Government might also initiate a program to develop working prototype equipment. The highly successful program of AID in developing a standardized portable radio unit followed this basic approach.

Finally, it might be hoped that the exposure of the problem here will be sufficient to spur industry to develop the required equipment.

AUTOMATIC CAR LOCATORS

INTRODUCTION

Reducing the response time in getting field units to the scene upon receipt of a call from a citizen has been shown in chapter 2 to be related to improving the probability of making an arrest. There are frequent instances when an unnecessarily long response time results from assigning a patrol car that may falsely appear to be the closest available patrol car. Automatic patrol car locators could reduce this problem.

At present, the locations of various patrol cars within a city are known only to the extent that they are patrolling in an assigned sector. As a result, the location of a patrol car is actually known only to within 1 to 4 miles traveling distance of its presumed location. Therefore, when handling an emergency call a dispatcher often requests any car in the vicinity of the incident to respond. This usually results in an unnecessarily large number of cars responding, with the closest car generally being one of the units.

There are many instances, however, when the closest car does not respond. For instance, a motor patrolman may not be aware that he is the closest available car to the scene. It was shown in chapter 2 that many calls that are classified as routine actually escalate into emergency situations before the police arrive. In the case of routine calls only one particular car is assigned and it often occurs that the car that is assigned is actually not the closest car. Car locator devices would make it possible to select and assign the closest available car.

Of equal significance, however, is the fact that car locator devices make possible more detailed control of the mobile forces. Knowing the locations of cars permits an intelligent redeployment of forces as emergency situations develop, avoiding overresponses and underresponses and the possibility that sections of a metropolitan area may be inadvertently left without police protection. For example, a report of a suspected burglary in progress is one of those cases that usually results in an unnecessarily large number of patrol cars responding to the scene. Car locator devices would permit assignment of the two or three cars closest to the scene, and if advisable, other cars could be strategically deployed along likely escape routes.

RESOLUTION REQUIREMENTS

The accuracy of resolution required is one which will reduce, to some acceptably low level, the probability of assigning the wrong car. As the number of available cars is decreased, the advantages of accuracy become less. In the extreme case of there being only one car available, accuracy becomes of no consequence since that *one* car is, automatically, the closest available car.

Dr. Mandell Bellmore performed an analysis to estimate the accuracy that would be required in any car locator system. This analysis assumes that the measure of the value of the police dispatcher knowing the exact location of the patrol cars in his district was the extent to which it would enable him to dispatch cars in a manner which would reduce the travel time associated with a request for police service. For purposes of the analysis, two systems were studied and compared. The first system is similar to the normal situation where the dispatcher does not have the information that a car locator would provide him. The second system simulates the situation where the dispatcher would have the use of a car locator having some specified accuracy of resolution. In both systems, cars were assigned to square beats. Each car is instructed to patrol its beat in an essentially random manner so that it is not possible to predict its exact location at any instant. For ease of discussion, assume that the beats are numbered (i.e., Beat 1, Beat 2, etc.).

Assume that a call for police assistance is requested from a location in Beat 10. In the first system the dispatcher assigns the car in Beat 10 to answer the call, providing it is available; in the second system the dispatcher, based on car locator information, assigns the car which is available and he believes to be closest to the location requesting assistance.

To determine the effect of car locator accuracy on the system, it is assumed that each beat is broken into square subbeats, or resolution cells. The car locator system can determine a car's subbeat but cannot specify its location within the subbeat.

The situation examined is illustrated in figure E-6, which depicts two adjacent square beats with car locator resolution distance one-third the beat size. We define "resolution" to be:

$$r=R/B$$

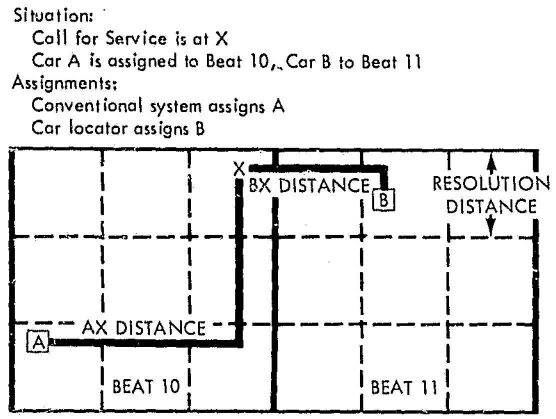
where: r = resolution
R = resolution distance
B = beat size

It should be noted that "resolution" as defined here for purposes of this analysis differs from the usual definition of resolution, since a larger value of resolution here implies more coarse position determination. This is shown in the two extreme cases: If $R=1$, then the dispatcher has no more knowledge in the second system than the first, and the two are identical. When $r=0$, then the dispatcher has perfect knowledge of the location of all cars and this corresponds to an error-free car locator system.

The measure of effectiveness chosen to compare systems is the difference in distance that must be driven to answer a call for police assistance. That is, the difference in distance between the car that the dispatcher assigns to the call and the car which is in fact closest to the call. To approximate the driven distance, distance is measured as the sum of the north-south distance and the east-west distance as is also illustrated in figure E-6. Time lost can be calculated from this measure by dividing by the unit's average speed.

The systems described were simulated on a digital computer. A square area containing 144 beats was simulated. Cars were assigned locations randomly within their beats. An out-of-service rate was specified for each run. A uniformly distributed random number between 0 and 1 was

FIGURE E-6. CAR LOCATOR CONCEPTS

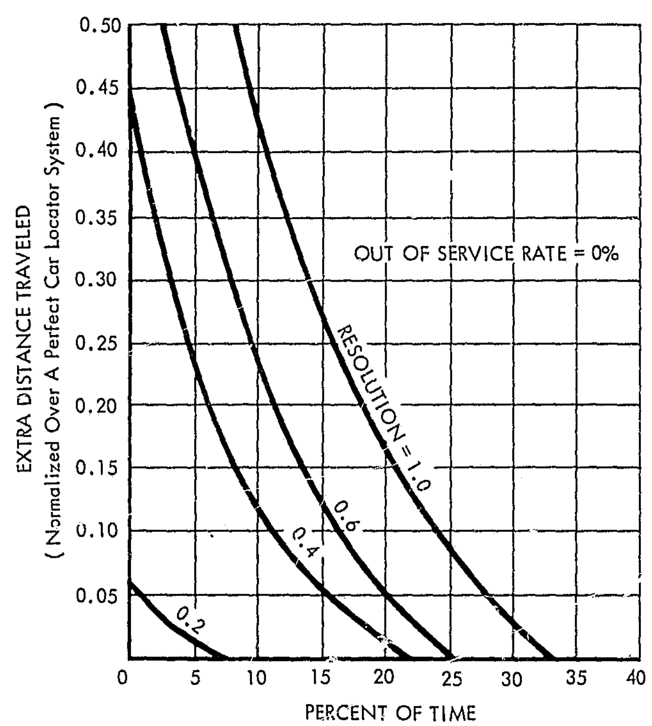


drawn for each car and if the number was less than the out-of-service rate, then the car was assumed to be previously committed and not available for answering a call. A call for service was then generated randomly within the area being simulated. The closest car which was available for service was determined and the actual distance between the call for service and the closest car was calculated. The car which the dispatcher believed to be closest under each assumed set of conditions was then determined. The distance between this car, believed to be the closest, and the call for service was then calculated. The difference, if any, between these two distances was calculated and recorded. The entire process was repeated 100 times and then new parameters (i.e., resolution distance and out-of-service rate) were read in and the simulation run again until all parameter sets had been evaluated.

The results of the simulation model are summarized in figures E–7 through E–9. These figures give the frequency of additional driving distance caused by assigning the wrong patrol car as the result of not having a perfectly accurate system. The curves show the additional distance traveled as the result of having different degrees of accuracy. The distance shown in these figures has been normalized to the beat width.

To obtain the actual distance one must multiply the distance read from the graph by the beat size (i.e., the length of one side of the square beat). If the beat was 1 mile by 1 mile, then the normalized distances are equal to the actual distance. From this figure it is seen that for a 1-mile beat size with 80 percent of the cars out of service, and with a resolution of 1 (i.e., no car locator) then 15 percent of the time there is at least 0.3 additional miles traveled which could be saved by a car locator. If the

FIGURE E-7. RELATIONSHIP BETWEEN CAR LOCATOR SYSTEM ACCURACY AND AVERAGE EXTRA PATROL CAR DISTANCE TRAVELED (Based upon 25 Monte Carlo trials)



beat were 2 miles by 2 miles then the additional distance would be 0.6 additional miles.

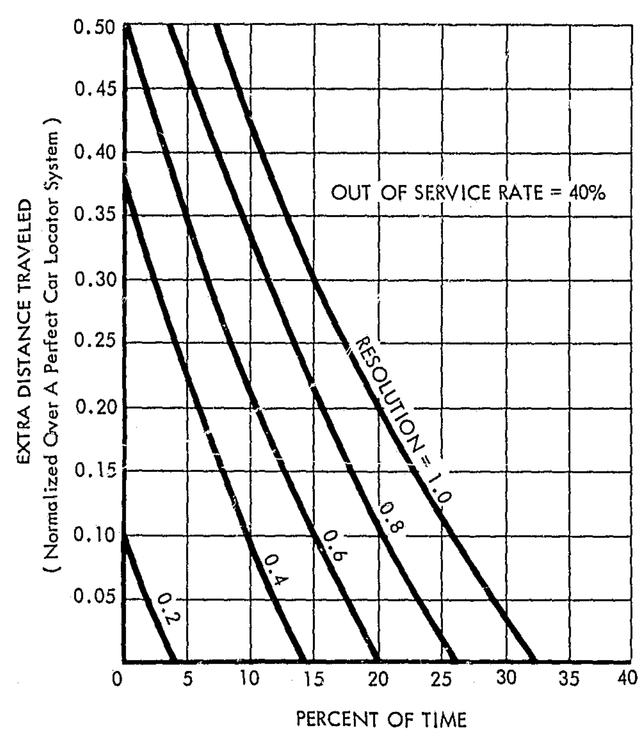
Note that approximately all the value of a car locator is obtained with a resolution of about 0.2. That is, if the beats are 1 mile by 1 mile, the subbeats should be ⅕ mile by ⅕ mile. Furthermore, resolution of 0.4 appears acceptable if there would be a dollar savings obtained by going to 0.4 resolution. This is particularly true for the higher out-of-service rates.

SOME POSSIBLE LOCATOR TECHNIQUES

With these relatively loose accuracy requirements, several car locator system designs can be considered. Four techniques show promise of providing the necessary accuracy at an acceptable level of cost:

- ☐ A system of patrol car emitters and callbox sensors.
- ☐ A modified radar transponder system.
- ☐ A medium-frequency radio-direction-finder system.
- ☐ A car-borne position computation and reporting system.

FIGURE E-8. RELATIONSHIP BETWEEN CAR LOCATOR SYSTEM ACCURACY AND AVERAGE EXTRA PATROL CAR DISTANCE TRAVELED (Based upon 100 Monte Carlo trials)

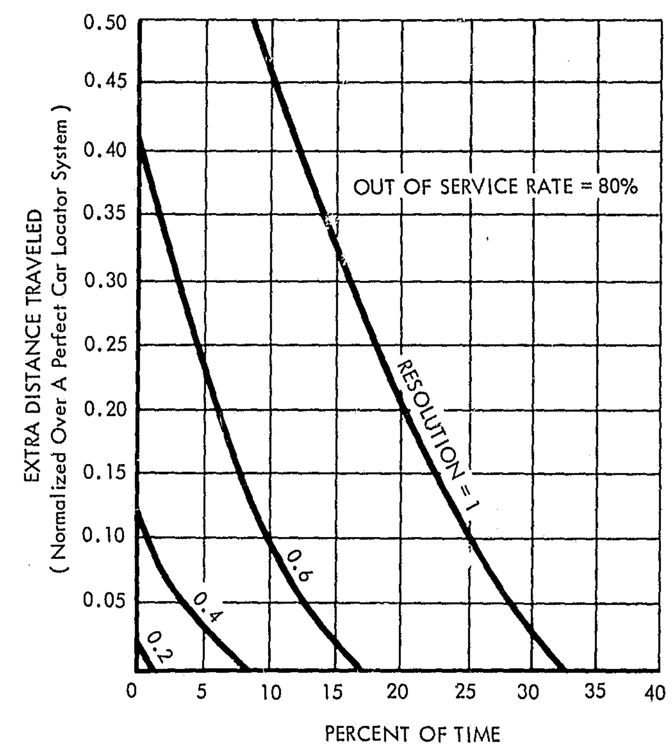


Patrol Car Emitter-Callbox Sensor System

In this system each car would carry some kind of magnetic, acoustic, or radio emitter that could be detected by a sensing device located in police callboxes. For example, the emitter could be a very low power electromagnetic radiator whose output could be detected by very simple receivers located in police department callboxes, fire department callboxes, or both. Information gathered by the sensors could then be sent back to the communications center over land lines.

Operationally, the system could work in the following manner: The emitter in each car could be a very low frequency induction field device or a very low powered MF or VHF radio transmitter. The emitter could employ solid-state circuit elements and operate from the car battery. It could be mounted near and operate in conjunction with the regular two-way radio and could share its antenna. It would be designed to radiate so little power that it could be detected only within a few tens of feet of its antenna. At these power levels no FCC license would be required. Each car's transmissions would be continuously modulated by an identity code, either a selected combination of tones or a coded sequence of pulses. While a solid-state or transistor type

FIGURE E-9. RELATIONSHIP BETWEEN CAR LOCATOR ACCURACY AND AVERAGE EXTRA PATROL CAR DISTANCE TRAVELED (Based upon 25 Monte Carlo trials)



modulator is preferred for reasons of reliability, long life, and compactness, it is also possible to provide a motor-driven keyer of the cam type such as that used in the coded fire alarm.

Locator receivers, or sensors, could be installed in each police callbox. Whenever a police car passed a callbox, the locator receiver would detect the car's coded signal. Depending on the exact design, the signal would most likely be demodulated at the callbox and would be automatically sent to the dispatching center over the existing callbox telephone line. At the dispatching center, the signal would be decoded to indicate identity and location.

There are then many ways of displaying that basic information. For instance, the decoded information could update the car location file in a computer. The computer could then generate a plan position display showing identity and availability. Also, it would be possible to query the computer for the identity of the car at a given location or, conversely, for the location of any particular car. In either case, the computer could automatically select the car closest to any call for police assistance.

Such a system could be used by passenger buses to summon police assistance. A decoded bus emitter signal could be sent from the dispatching center to the bus company to alert them to the situation. The location of the bus could also be presented on the computer-driven display.

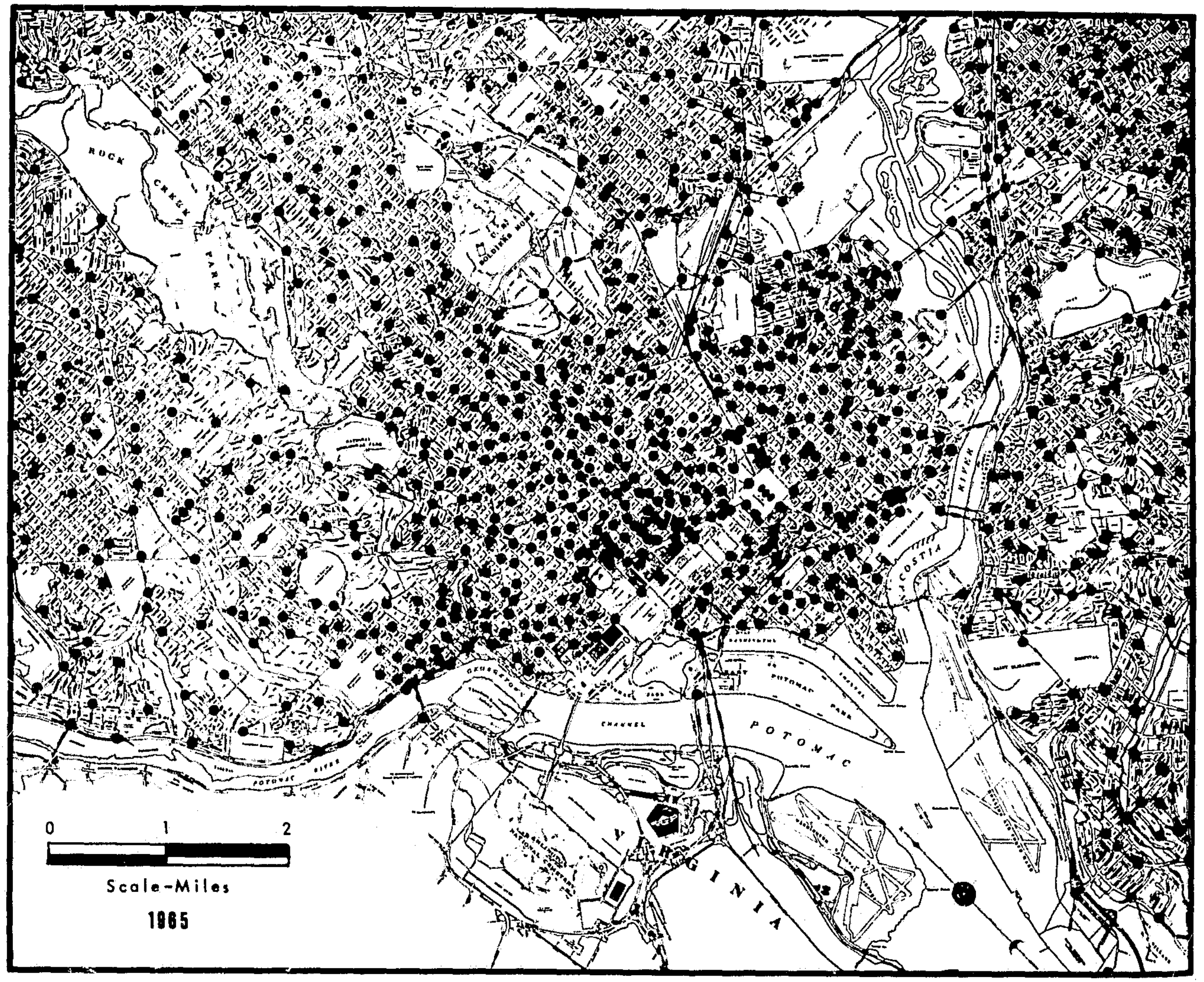
In Washington, D.C., for example, there are approximately 920 police callboxes (fig. E–10), about 14 per square mile or one every quarter of a mile. This would provide sufficient accuracy for patrol car location. If finer accuracy were desired, consideration could be given to locating sensors in the 2,000 D.C. fire callboxes.

If there were not a sufficient number of callboxes in a city, or if the callboxes use party line circuits, it may be necessary to use carrier derived circuits which can be superimposed upon existing physical circuits, such as fire and police cables, without impairing the present service. The carrier or radio frequency technique is widely used in the field of telephony, radio, and powerline telemetry and control. In telephony, a significant portion of all trunk and subscriber circuits are carrier derived without impairment of the physical services at a cost well below that of additional circuitry.

The inverse of this technique could also be employed with coded emitters installed at fixed locations along the street and sensors installed in patrol cars. A radio link would then be needed in the car to relay the car's identification and location to the communications center.

The emitter and detector devices should be comparable in cost to the transmitter and receiver devices used with automatic garage door openers. In large volumes, it is estimated that the emitter units would cost about $20 each and the callbox detector units about $30. Thus, the

FIGURE E-10. POLICE CALL BOX LOCATIONS IN THE DISTRICT OF COLUMBIA



equipment for 1,000 callboxes and 200 patrol cars would cost approximately $34,000.

To this must be added the installation costs and the cost of the central display system, which is difficult to estimate at this time. If a city has a suitable computer available for time sharing and it chooses to use the simplest type of display system, the cost may be as low as $100,000 to $200,000.

Modified Radar Transponder System

Because of multipath problems, conventional radar transponder techniques cannot be used as a means for locating police cars. In a conventional radar transponder system a radar interrogator would transmit a coded pulse train in the form of a short burst lasting no more than a few microseconds. The transponder in a patrol car would recognize its code and reply with a short signal pulse. The transit time between transmission of the interrogation pulse train and receipt of the transponder reply would be a measure of the distance to the car being interrogated. Azimuth would be determined by the pointing direction of the interrogator antenna.

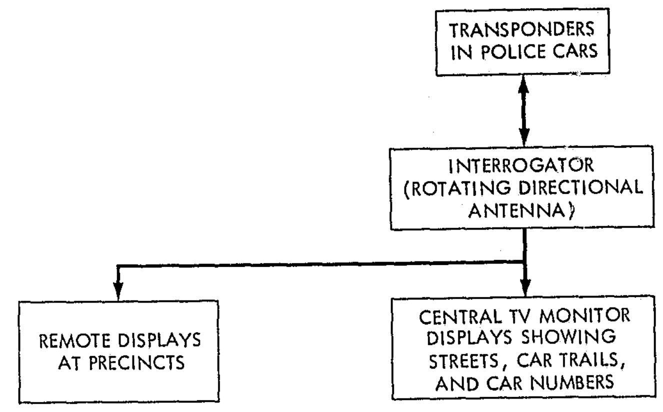
Unfortunately, the coded pulse train would generally be unrecognizable to the intended transponder because of the overlapping of signals as they would be received over the various paths. This multipath phenomenon was investigated by W. R. Young and L. Y. Lacy.[11] Their investigations indicate that, although VHF pulse signals are modified severely by reflections in an urban area, they do get through, with the leading edges of the pulses substantially unaffected in almost every instance. This suggests that some modified radar transponder system not using coded pulse trains might be used.

Two techniques have been suggested. One would be to use the selective signaling system of the car radio system to sequentially turn on transponders for a fraction of a second. During this time, the transponder would be interrogated and range and bearing determined based on the leading edge of the pulses. No coded pulse train would be required to identify the car being interrogated because this would have been accomplished by the selective signaling technique. This technique has the disadvantage that the tones transmitted in the selective signaling process would load up a voice channel to such an extent that it would not be useable for voice communication.

A second technique uses a periodically synchronized timing system in each car to turn on the car's transponder at predetermined short periods of time. In this technique (fig. E–11), a central beacon interrogator with a directional antenna, rotating mechanically or electronically, transmits pulse interrogations. The interrogations and replies are essentially single pulses with a pulse width in the order of 2 μ sec. Two different frequencies (in the same band) are used, one for interrogation and the other for reply. The frequencies used may be in the 150 or 450 MHz bands, or perhaps in the vicinity of 1000 MHz.

The basic idea in the approach is the use of a relatively high interrogation rate by the interrogator (in the order

FIGURE E-11. POSSIBLE RADAR CAR LOCATOR SYSTEM



of 5 kHz), coupled with a time apportionment system where any given transponder replies to 1 and only 1 interrogation out of roughly 100 interrogations; the interrogation answered by each transponder is different and represents the transponder's identity.

At the start of every 100-interrogation cycle, a special synchronizing signal is transmitted. Each transponder then starts to "count off" successive interrogations until its assigned one is reached. The transponder replies to that interrogation (and no other interrogation) with a single pulse. Thus, each transponder replies to every 100th interrogation at a rate of about 50 Hz, and each interrogation is replied to by only one car. This makes it possible to see closely spaced cars despite reflections, and provides for a very simple identification that does not require either interrogator or transponder pulse modulation.

An important question to be resolved before a final judgment can be made on the feasibility and practicality of this system is what are the effects of reflections on effective interrogator antenna directivity. It is possible that the multiple transmission paths (via different reflections) may cause effective beamwidth broadening and boresight shift, and presence of false targets at certain values of azimuth. The beamwidth broadening, if not too severe, could be tolerable. The false targets, resulting from the presence of large reflecting surfaces in certain directions, may be reduced to an acceptable level by displaying continuous car trails (for true targets, which would make sporadically received reflections easily distinguishable from true targets).

Some limited field tests are needed to observe the actual effects of reflections and to verify the feasibility of the basic approach.

Medium Frequency Radio Direction Finder System

Because of their relatively long wave length, MF radio signals are not characterized by extreme multipath propa-

[11] "Echoes in Transmission at 450 Megacycles from Land-to-Car Radio Units," W. R. Young and L. Y. Lacy, *Proceedings of the I.R.E.*, March 1950.

gation over short distances. Consequently, conventional direction finders having an accuracy of about ±3° can adequately determine the direction of a radiating transmitter even when the transmitter is located in the midst of tall structures, such as in the downtown area of a large city. Thus, they could be used with triangulation to locate police cars equipped with a simple, low power MF (2–3 MHz) transmitter.

Since an accuracy of one-fourth mile is sufficient for 1 mile square patrol beats, bearings taken on the average of twice every minute could provide the required accuracy. Since it would take on the order of 2 to 3 seconds for each bearing, a simple one-frequency system could keep track of from 10 to 15 cars. In suburban areas where beats might be as much as 4 miles on a side, an accuracy of 1 mile would suffice, and bearings would be needed once every 2 minutes. Such a system should be able to track 40 to 60 cars.

The system (fig. E–12) would consist of the following basic elements:

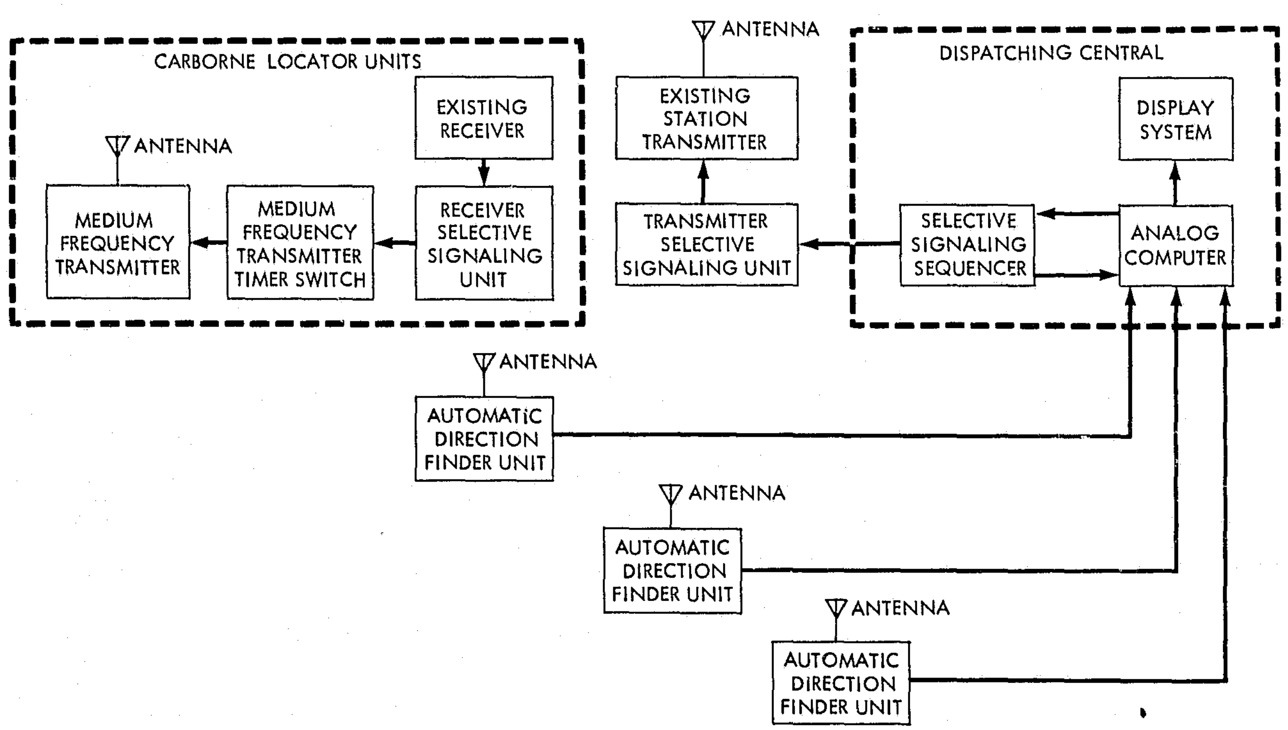
- ☐ A "selective signaling" device operating in conjunction with the existing police radio communication link that would sequentially activate the MF radio transmitter of each car.
- ☐ A simple continuous wave (c.w.) radio transmitter in each car.
- ☐ At least three automatic radio direction finding stations.
- ☐ Computer to compute the coordinates of each car from the bearing information received from the direction finding stations.
- ☐ Display device to display the location of each car as determined by the computer.

The selective signaling device envisioned here is included in most existing police mobile radio systems. Selective signaling is accomplished by sending a series or combination of different tones. The receiver can then operate a switch to perform some intended function as turning on a light or a siren. In this case, it would turn on the car's MF radio transmitter for 2 to 3 seconds.

The transmitter could be a very simple device consisting of little more than a crystal oscillator. The car transmitter would not have to transmit any coded identification signal since identity of the car would have been established through the selective signaling process.

The major problems foreseen with the direction finder system are that the selective signaling device would seriously load one communication channel, and the time

FIGURE E-12. BLOCK DIAGRAM OF MEDIUM FREQUENCY CAR LOCATOR CONCEPT



required to take a bearing would limit the number of cars that could be accommodated by a one-frequency system. It might be possible through coding techniques to increase by a factor of two or three the number of cars accommodated and still stay within the 100-Hz bandwidth limitation of these police frequencies.

The approximate costs for a one-frequency system (capable of handling up to about 25 cars) based on available information may be broken down as follows:

Selective signaling feature	$75 per car, including installation.
Carborne transmitter	$75 per car, including installation.
Direction finder units	$6,000 for required set of three including installation.
Triangulation computer and display system.	Uncertain.

Carborne Position Computation and Reporting System

Carborne position computation and reporting systems are here taken to include all systems in which the patrol car continually computes and records its own location for transmission to the dispatching center upon receipt of a proper interrogating signal. There are at least three different methods by which this system could be instrumented. They are as follows:

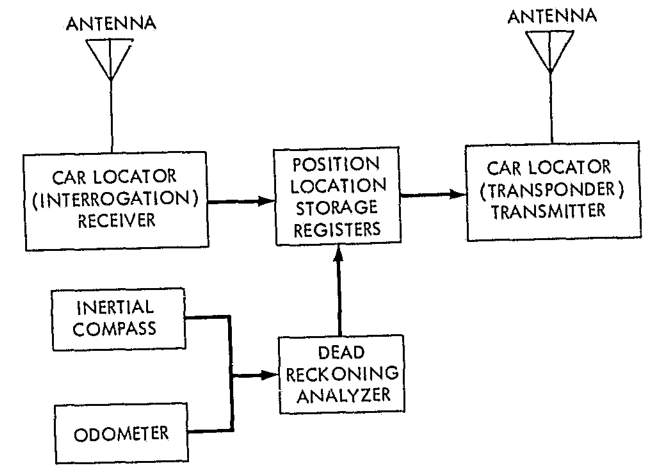
Inertial compass and odometer system.
Magnetic compass and odometer system.
System for frequently inserting by manual means the location of the car into the car location recorder.

The first two techniques' all involve automatically feeding direction and distance information into a dead-reckoning analyzer. The dead-reckoning analyzer then computes the location of the car and feeds this information into a digital data storage register. Every few seconds, upon computer controlled radio command, the stored information would be forwarded to the dispatching center for processing and display. The third technique would accomplish the same thing by manually updating the car's position.

All three techniques depend on continual updating of a digital data storage register in the car with the latest computed car location information. Each car would be interrogated in turn with a coded signal. Interrogation signals would be transmitted upon computer command from a centrally located interrogation transmitter. Interrogation would be at a high rate so that every car would be interrogated once every few seconds. The interrogation receiver of each car would recognize its own code and would immediately transmit to central the stored car location information via its car location transmitter. A data processing device at the dispatching central could control and continually update the display of each car's location.

The inertial compass and odometer system (fig. E–13) would utilize a small gyro compass that would provide direction information and an attachment to the odometer of the car to provide distance information. This direction and distance information would be fed into the dead-

FIGURE E-13. INERTIAL COMPASS AND ODOMETER CAR LOCATOR SYSTEM



reckoning analyzer that would compute the "x" and "y" coordinates of the location of the patrol car.

The system, as described, is similar to an inertial guidance system. Many highly sophisticated, extremely accurate and very expensive inertial guidance systems have been developed in connection with aircraft and missile development. What is required here is an inexpensive and relatively inaccurate system. Great accuracy is not required in absolute terms, nor does it matter greatly if the accuracy deteriorates rather rapidly with time; the system can be periodically recalibrated by the officer or officers manning the patrol car. Unfortunately, no relatively inaccurate, simple, and cheap inertial guidance systems appear to be available. Nevertheless, it is the opinion of at least one specialist in the field that inertial guidance systems of the required accuracy could be developed to sell for less than $100 each in quantity production lots.

The magnetic compass and odometer system is virtually identical to the previous system except that a magnetic compass replaces the inertial compass. Unfortunately, carborne magnetic compasses would normally be subject to variations in magnetic field which would introduce errors that probably would be unacceptably high. A higher resolution could be obtained through utilizing dual magnetic compasses and averaging readings.

With the system of manual updating of position location storage registers, a city is divided into relatively small sectors. Whenever a patrol car moves from one sector to another, the new sector number is manually fed into the position location storage register. This system is presently under test by the *carabinieri* in Rome, Italy.

This technique is the most simple to instrument and the most foolproof. Its main drawback is the requirement for continual manual updating of the position location storage register. The system would not appear practical to use with one-man patrol cars.

In summary, the three versions may be related as follows:

- ☐ The feasibility of the inertial compass and odometer concept depends on the practicality of developing a low cost inertial compass.
- ☐ The magnetic compass and odometer version does not appear to be a practical system unless its cost can be substantially reduced.
- ☐ A system based on manual updating of the position location storage registers would not be practical for one-man patrol cars, and it does not seem to be enough of an improvement over present techniques to be worthy of further investigation.

Summary

All four of the basic car locator techniques that have been discussed appear to be technically feasible. On the basis of the limited investigation possible here, the patrol car emitter-callbox sensor system and the modified radar transponder system appear to offer the most promise.

Since the patrol car emitter-callbox sensor system is expected to be preferred in cities with existing street installations, and the modified radar transponder system preferred system in other cities, operational feasibility tests of both should be pursued.

SURVEY OF EXISTING CRIMINAL JUSTICE DATA PROCESSING FACILITIES

by Claude Walston

Contents

INTRODUCTION

The use of data processing by agencies in the criminal justice system has undergone a pronounced increase in the past 5 years and current indications are that it will experience an even greater growth in the future. One of the big advantages of data processing equipment is its inherent flexibility; this flexibility can be a mixed blessing, however, to the agency which is just planning to install a data processing system. The question of which applications should be implemented first and what equipment to use can be difficult to answer because of the numerous alternatives that are possible. The experience of the agencies which have already installed data processing equipment should prove valuable to those agencies which are just beginning to consider its use. Accordingly, as one part of the information handling study of the Science and Technology Task Force, a questionnaire was mailed to 45 agencies which were known to be using data processing in their operations.

Thirty-two replies were received in response to the questionnaire. The data from these responses have been used to develop the discussion in the following section and provide the basis for the summary tables presented therein. The last section presents the detailed information supplied by each agency which responded to the questionnaire and should serve as a valuable finder list for any organization which is planning to install a data processing system. It will serve to identify agencies which have developed and implemented similar data processing applications and can thus be contacted for further guidance and advice.

ANALYSIS SUMMARY

PATTERN OF DEVELOPMENT

The application of data processing by criminal justice agencies in general has followed a fairly standard pattern of development. The majority of those agencies that are now using data processing started by utilizing a basic punched-card processing system. This basic system was expanded by adding new punched-card machines as the size and complexity of the applications to be processed increased. When the scope of their operations began to exceed the capability of their punched-card system, and as their financial resources permitted, the solution was to install an electronic data processing system to replace the punched-card system. In a number of instances, the transition from punched-card machines to the electronic data processing system was made easier by retaining the punched-card data base, and, in effect, operating the system as a card computer. This system was then capable of being upgraded by the addition of magnetic tape storage or disk storage when it became necessary to accommodate larger loads, add more flexibility and increase throughput of data. The final step was to install an on-line electronic data processing system to provide even more effective support to a wider number of users within the agency.

This pattern of system development has obviously been one of system evolution. A number of the agencies now using electronic data processing systems have followed this pattern. However, some agencies have bypassed certain steps in this development cycle and those agencies just beginning to use data processing will also be able to bypass some of these steps by building on the experience of those who have preceded them. The evolutionary pattern of development has one significant advantage, however, in its orderly growth; the operating experience gained in one phase of the system cycle can be of great value in analyzing and designing the next phase of the system. Perhaps even more significantly, the early phases permit the orderly development of a data base in a machine readable form, thereby minimizing to a certain extent the problems and cost associated with converting from a manual operation to a data processing operation.

PUNCHED-CARD PROCESSING

Punched-card processing has enjoyed wide application by a number of police departments. This is not surprising when we remember the long history of usage of punched-card equipment, the variety of such equipment available, and the ability to configure punched-card systems whose size and costs can be constrained to fall within the financial means of all the larger cities and their police departments. As a matter of fact, several of the organizations responding to the questionnaire reported that they had started using punched-card equipment more than 20 years ago, and one major police department had first used punched-card equipment in 1923.

One aspect of the survey was an attempt to establish certain cost and planning factors which might be of value to other agencies which are just now planning to implement their own systems. The information was derived from an analysis of the questionnaires returned by those organizations which are using punched-card processing systems. Several interesting facts were revealed by this analysis. We had expected to find that the population of the city being served by the police department would have a significant impact on equipment and personnel costs. However, this was not the case. For example, the Portland, Oregon, Police Department, serving a population of approximately 380,000, spends $2,000 a month for rental of its equipment while the Cleveland, Ohio, Police Department, serving a population of 810,000, pays a monthly rental of $1,834. The punched-card equipment costs for cities in the 200,000 to 900,000 population range are from $1,400 to $2,000 per month rental, but are not directly proportional to population. This narrow spread is not too surprising, however, if we note that there is a basic set of equipment which is needed for any punched-card processing system; namely, the key punch, sorter, collator, reproducer, and accounting machine. This sets a lower limit for the cost of the system. Any further variations are caused by the number of individual pieces of equipment used and by the operating speeds or the specific operating features ordered for each unit. The rental cost is directly influenced by the speed and complexity of the unit.

In the case of the personnel required to operate the punched-card system, we found the same clustering as we did for equipment costs. The various police departments for cities in the 300,000 to 900,000 population range reported that the size of their data processing staffs ranged from 6 to 11 people. (Cleveland, Ohio, reported 6 and Portland, Oregon, reported 11.) This figure includes one supervisor. The average cost of the salaries reported for the punched-card data processing staffs ranged from $5,400 to $6,700 per year for all the police departments reporting in this category. The average nationwide figure was $6,100 per year. All of these figures include the supervisor's pay.

Nearly all those departments using punched-card equipment estimated that they spent three to nine man-months of effort in planning their system and preparing card layouts, report formats, and related system activities.

By its nature punched-card processing is generally restricted to batched operations which are essentially statistical and historical in nature. (Certain police departments do possess electronic statistical machines and collators which permit sophisticated searching but these are in the minority.) This has naturally influenced the types of police applications that have been developed for the punched-card systems. In spite of the restrictions inherent in the punched card, a wide range of applications have been developed. Table F-1 lists a number of the applications that were reported by the police agencies which responded to the questionnaire. These applications seem to fall into four main categories: crime-related applications; traffic-related applications; police operations; and police administration.

Table F-1.—Police Punched-Card Applications

Crime-related applications:	
Criminal offenses file (crime type, location, modus operandi factors, suspects, disposition, etc.).	Used to produce statistical reports, crime by location reports, etc.
Arrested persons file (name, physical description, modus operandi).	Special reports and special searches.
Juvenile activity file	Statistical reports and special studies.
Stolen property and stolen auto files	"Hot" lists.
Fingerprint file	Special searches.
Traffic-related applications:	
Traffic accident file (type of accident, location, conditions, etc.).	Statistical reports and special analyses.
Traffic complaint file (name, licenses, location, violation number).	Prepare traffic court docket, analytical studies.
Parking citations (who, when, what type)	Citation accounting and fines collection.
Police operations:	
Police activity file (type of run, time out and in, arrests, etc.).	Operational and statistical reports.
Jail bookings	Booking control.
Motor vehicle registration file	Master file of license numbers vs. names and addresses.
Police administration:	
Personnel records.	
Timekeeping.	
Payroll authorization.	
Vehicle expense data.	

In crime-related applications, all the police departments reporting have developed a crime or criminal offense file. This file contains data on each crime reported, what type it is, when and where it occurred, any pertinent descriptive data, pertinent modus operandi factors, disposition, etc. This file is then used to develop a variety of statistical reports, including the Uniform Crime Reports, reports of crime by type, and reports of crime by location and time of day to assist in planning distribution of patrols. A number of departments maintain a file on all persons who have been arrested, containing such data as their physical characteristics and modus operandi to permit searching on these parameters. In most jurisdictions a separate file is maintained for juvenile activity, giving pertinent data on youthful offenders and their activities. Files are maintained on stolen autos and stolen property and are used to prepare "hot" lists for patrolmen and detectives. Some departments maintain a fingerprint file in punched-card form to facilitate searching for prints.

In traffic-related applications, nearly all departments reported maintaining a traffic accident file, containing pertinent data such as location, time, causes, circumstances, etc., on each reported traffic accident. This file is used to generate statistical and special reports to permit better planning and coordination of police traffic activities. In several instances a traffic complaint and court citation file has been established to identify both the individuals involved and the circumstances under which they were issued traffic citations. This information is used for generating the traffic court docket and for following the cases through to their final disposition. A similar application has been developed for parking citations to permit control of parking citations issued and to allow follow-through on collection of fines.

In the area we have defined as police operations, the main application has been concerned with police activity, accumulating data on the nature of dispatching calls, time spent on each, arrests made and other pertinent activity data to enable the generation of reports and special studies to permit better direction, planning, and coordination of police activities. Other applications in this area are: jail bookings to identify who was booked, where, and what the disposition was; and a motor vehicle registration data file to permit rapid determination of the owner's name and address through the auto license number.

In police administration, punched-card systems are being used for such purposes as maintaining personnel data on all uniformed and civilian personnel in the department, keeping track of employees' time for payroll and vacation purposes, and for budget and expense control for police department vehicles.

Surprisingly, very little application has been made of punched-card processing in the courts. However, both the Court of Common Pleas of Allegheny County (Pittsburgh) Pa., and the Los Angeles Superior Court have made valuable use of punched-card processing for court operations. With limited investments in equipment and personnel, they have been able to provide effective support in such areas as providing case-by-case records of cases filed and at issue, providing master calendar attorney scheduling, centralized court statistics, etc. In the case of the Court of Common Pleas of Allegheny County, the equipment costs are $272 per month and only three personnel are required to operate the system. The Los Angeles Superior Court shares the punched-card equipment and personnel with the county clerk so its operating costs are kept low.

ELECTRONIC DATA PROCESSING

The electronic data processing system presents the potential user with a much more bewildering number of alternatives and decisions than did the punched-card processing system when it was introduced. This stems not only from the great flexibility of the electronic computer but also from the wide variety of central computing equipment and peripheral equipment that are on the market today.

When they were initially introduced, electronic computers were so expensive that only a few of the largest agencies could contemplate their use. The advent of the so-called third generation computers with their increased performance and reduced prices have made the electronic data processing system available to a much larger number of users. With the increased utilization of on-line systems and the relatively recent development of time-sharing systems, the prospective user has available some additional alternatives which can also offer the computing capacity that he needs at reduced costs.

Several of the larger criminal justice agencies have data processing requirements of sufficient magnitude to justify their own electronic data processing installations. However, another trend has been the development of centralized municipal data processing centers which are designed to provide data processing support to all the municipal agencies who need it, including the police department and the municipal courts. This trend to centralization, while very useful in making electronic data processing accessible to those smaller agencies who would otherwise be excluded because of their size, is by no means limited to the smaller city, since the city of Los Angeles has elected to take this approach to satisfy its citywide processing needs.

Among the police departments now using electronic data processing systems, a large variation was noted in the amount of effort spent in systems analysis prior to implementing and installing their systems; the effort ranged from 6 to 75 man-months and, as would be expected, was a function of the size of the department. The equipment costs varied over a wide spectrum but did not seem related to population. Three of the police departments reporting were in the enviable position of having all their computing costs (including equipment and personnel) paid by their respective city governments. In three other cases, the police departments shared computers with other local governmental agencies and were, therefore, able to utilize data processing systems at much lower costs than if they had to operate their own computing systems. For those police departments operating in an off-line mode (as contrasted to an on-line system) the cost of the equipment was reasonably consistent, ranging from approximately $4,500 per month in Indianapolis, Ind., to $5,000 a month in Philadelphia, for example. For those departments which have their own on-line systems, the equipment costs were considerably higher, ranging up to $25,000 a month rental or a purchase cost of $1,140,000, if a lease/purchase option is exercised, as in the case of St. Louis.

The size of the data processing staff varied in accordance with the size of the city, ranging from 5 people in Indianapolis to 21 people in New York City. The composition of a typical police department data processing staff of 10 people would be 1 supervisor, 3 programer/analysts, and 6 computer and machine operators. The complexity of an on-line system, however, is such that larger staffs are required to implement and operate them. The Chicago Police Department, for example, has 15 programer/analysts on its staff, while the St. Louis Police Department has 12. The total size of the St. Louis Police Department data processing staff is 72 people; this figure includes 45 terminal teleprocessing operators. The average salary for electronic data processing staff personnel is higher than those for punched-card systems, averaging $7,200 a year for those agencies responding to the questionnaire. Experienced computer programers are in relatively short supply today and their salaries are the main factor contributing to the higher average salary of electronic data processing personnel. While programers' salaries were not reported separately, they would approximate $10,000 per year.

A review was made of the various applications which are currently in operation on police department computers or are planned for the future. Table F-2 is a summarization of those applications. As in the case of the punched-card systems, those applications are organized into the four categories of crime-related applications, traffic-related applications, police operations and police administration. A comparison of table F-1 and table F-2 shows a great similarity of applications but this is not too surprising since most departments now using computers previously had punched-card systems. What they have done is to take their existing applications and data bases and upgrade these to the electronic computer adding more capability and flexibility in the process.

Table F-2.—Police Computer Applications

Crime-related applications:	
Criminal offense file (type of crime, where, when, modus operandi factors, etc.).	Used for statistical reports and analyses.
Criminal arrest file (who, where, when, disposition, physical characteristics, modus operandi).	Followup control, analyses and special searches.
Juvenile criminal activity	Statistical reports and special studies.
Warrant file	Wanted lists and special searches.
Stolen property	"Hot" lists.
"Hot desk" applications (wanted persons, stolen autos, stolen property).	On-line queries for special and timely data.
Traffic-related applications:	
Traffic accident file (nature of accident, location, circumstances, who, etc.).	Statistical reports, traffic studies.
Traffic citations (who, disposition)	Traffic court docket preparation, citation accounting.
Parking violations (who, disposition)	Mailing and followup for delinquents, parking ticket accounting.
Police operations:	
Police service analysis (location, type of run, car, time, etc.).	Operational reports, planning data.
Beat boundaries and patrol distribution (offenses, locations, day and time variations, data, etc.).	Establish patrol patterns and boundaries.
Communications switching	On-line message switching and control, communications with other computing systems.
Jail arrests (who, cell number, disposition)	Prisoner control.
Location file (street addresses and city and patrol boundaries).	Dispatching.
Auto registration (license numbers vs. owner name and address).	Special searches.
Police administration:	
Personnel data (name, serial number, training, experience, etc.).	
Inventory control file (fixed assets, location, description).	
Vehicle fleet maintenance accounting.	
Financial accounting.	
Budget analysis and forecasting.	

In punched-card systems there is a tendency to develop many separate files to facilitate the type of processing that has to be done. These files, although treated separately, have many data elements in common. Many police departments followed this trend and when they converted to electronic computers they maintained their numerous separate files. Now that the various agencies have gained experience in the use of computers, they are starting a newer and more desirable trend. This is the consolidation of their many files into fewer but more extensive files. These consolidated files, while structurally more complex, can be designed to permit faster access, and as a result they facilitate demand searches in addition to the batch processing approach which was necessary in punched-card systems. Examples of these consolidated files are persons files where information about victims, suspects, arrested persons, warrants, and suspicious persons can be consolidated to permit quick on-line access for the patrol officer or investigative officer who needs this information to carry out his duties. Another example is the establishment of a serial number file which can be organized for rapid searching on such items as license numbers, article serial numbers, stolen auto numbers, etc.

A number of the agencies responding to the questionnaire reported that they are in various stages of planning or procuring new equipment to convert their systems to on-line systems. There is also a continuing need for batch processing operations; the statistical analyses, special reports, and management studies still will have to be done. The need thus exists not for on-line systems alone, but for on-line systems which are also capable of doing background processing.

Two capabilities that are important to the operation of criminal justice agencies are somewhat conspicuous by their absence from the applications list. These are fingerprint and text (report) searching. Our present ability to do either in a completely effective manner is limited by the current state of the art. Continued emphasis needs to be applied to the development of such capabilities and to incorporate them into the existing operating systems as they become available.

In addition to these capabilities, there are several other developments underway which should be mentioned, since they will also have long-range impact on the development of future systems. The New York City Police Department is in the process of advertising for bids from several contractors for implementation of their SPRINT (Special Police Radio Inquiry Network) system which is designed to increase the speed of their radio dispatching operation. At the State level, the New York State Identification and Intelligence System is developing an on-line system with a comprehensive data base to facilitate information sharing among the criminal justice agencies in New York State. In the corrections area, the State of California is planning for the installation of a correctional decisions information system to meet the needs of decision-makers within all levels in the State. In addition, the Office of Law Enforcement Assistance (OLEA) is funding several studies aimed at improving the information

processing and management capabilities of law enforcement agencies.

APPLICATIONS DATA

This section contains the data received from those agencies which responded to our questionnaire. It has been organized into city and State police, courts, and corrections agencies. Computer systems have been separated from electric accounting machines.

Table F-3 presents details on the individual installations, types of equipment, equipment costs, operating personnel, installation dates, and future equipment plans.

Table F-4 lists the uses to which equipment is now being put and planned applications for the future.

Table F-3.—Criminal Justice Data Processing Facilities

Agency and key individual	Equipment currently used	Rental cost per month	Purchase price	Personnel: Supervisory	Personnel: Systems analyst	Personnel: Machine operator	Personnel: Programer	Annual salaries	Date started using data processing equipment	Date current equipment installed	Planned electronic data processing equipment: Type	Planned electronic data processing equipment: Date
City Police—Electric Accounting Machines:												
Baltimore City Police Department, Baltimore, Md. 21202 (Mr. James Burke).	Electric accounting machine [1]	N.A		2	0	5	0	$31,000	1950	1950	360 [2]	1968
Boston Police Department, Boston, Mass. 02116 (Dep. Supt. J. J. Bonner).	do [1]	$1,766		2	0	8	0	45,000	1958	1958	360/30	1967
Cleveland Police Department, Cleveland, Ohio 44114 (Sgt. H. A. Blackwell).	do [1]	$1,834		1	[3] 4	5	[3] 6	N.A.	1937	1964	360/40 [4]	1968
Los Angeles County Sheriff's Department, Los Angeles, Calif. (Sgt. Rosemary Hill).	do	$3,000		4	0	14	0	104,020	1955	1959		
Los Angeles Police Department, Los Angeles, Calif. (Lt. G. E. Conroy).	do	$4,283		2	0	18	0	133,932	1923	1955	360/40 [2]	1967–68
Oakland Police Department, Oakland, Calif. (Fred Fong).	do	$1,428		1	0	9	0	66,864	1950			
Portland Bureau of Police, Portland, Oreg. 97204 (Capt. J. E. Nolan).	do	$2,000		1	0	10	0	68,000	1940	1957	360	1967
San Diego Police Department, San Diego, Calif. (Lt. J. W. Baker).	do	$400		1/4	0	2	0	N.A.	1940	1940	360	1967
Seattle Police Department, Seattle, Wash.	do	$890		1	0	10	0	59,640	1947			
City Police—Computer Systems:												
Chicago Police Department, Chicago, Ill. (R. J. Golden).	1411 computer, 1301-2 disk storage, 729-V tape drives (6), 1014 remote terminals, (12).		$400,000	15	11	78	4	630,000	1962	1964	N.A	1968
Detroit Police Department, Detroit, Mich. (Chris Kotsopodis).	1401 computer, 1311 disk drive, 729 tape drives (4), 1050 terminals (5).	$13,000		2	0	14	4	130,000	1932	1963	360/40	1968
Fort Worth Police Department, Fort Worth, Tex. (T. Morris, Director).	1401 computer [5]	$1,887	340,000					122,761	1954	1963	360/30 (Interim) 360/40.	1968–70
Indianapolis Police Department, Indianapolis, Ind. (Sgt. E. Gallagher).	1440 computer, 1311 disk drive (3), 7335 tape drive (2).	N.A		1	0	1	3	55,000	1958	1965		
New York City Police Department, New York City, N.Y. (Dep. Insp. J. H. McCabe)	1401 computer, 729 tape drive (4), 1311 disk drive.	$1,210	338,648	4	6	5	6	N.A.	1951	1963		
Philadelphia Police Department, Philadelphia, Pa. (Capt. J. C. Herron).	1401 computer	$5,000		3	4	27	4	185,000	1954	1966	360/30	1958
Phoenix Police Department, Phoenix, Ariz. (D. McKay).	415 GE computer, tape drive (4)			1	0	1	1	10,490	1957	1966		1968
San Antonio Police Department, San Antonio, Tex. (G. Davis).	1401 computer	$250+$50/hr.[6]		1/2	1/2	4	1/2	20,000	1957	1963		
St. Louis Metropolitan Police Department, St. Louis, Mo. (S. W. Hovey).	7040 computer, 7740 switch, 7330 tape drive (5), 1311 disk drive, 2302 disk, 1050 terminals (8).	$25,000		7	12	8	0	420,000	1954	1964		
Tucson Police Department, Tucson, Ariz. (Lt. K. Maurer).	1401 computer [5]	$196 (PD) $4,330 (CDP)		0	0	3	0	11,160	1963	1963	360/30 [2]	1967
Washington Metropolitan Police Department, Washington, D.C. (Insp. J. V. Wilson).	360/30 computer [5] tape drives (4), disk drives (2).	$1,485		0	1	0	1	70,000	1965	1966		1967
State Police—Electric Accounting Machines:												
Arizona Highway Patrol, Phoenix, Ariz. (Lt. L. Beddome).	Univac 1004 computer, VI-C tape drives (2).	N.A		1	0	3	1	24,828	1955	1963	360/30	1966
Michigan Department of State Police, East Lansing, Mich. (Lt. J. R. Plants).	Electric accounting machine	$2,135		1	0	-	0	40,862	1952	N.A.	Burroughs 5500	1967

For footnotes, see end of table.

Table F-3.—Continued

Agency and key individual	Equipment currently used	Rental cost per month	Purchase price	Personnel: Supervisory	Personnel: Systems analyst	Personnel: Machine operator	Personnel: Programer	Annual salaries	Date started using data processing equipment	Date current equipment installed	Planned electronic data processing equipment: Type	Planned electronic data processing equipment: Date
State Police—Electric Accounting Machines—Continued												
New Jersey State Police, West Trenton, N.J. (Capt. V. E. Galassi).	Electric accounting machine	$1,678		2	0	7	0	$46,783	1938	1952	(7)	
Pennsylvania State Police, Harrisburg, Pa. (Sgt. J. R. O'Donnell).	do[1]	$1,650		1	0	12	0	47,000	1962	1964		
State Police—Computer Systems:												
New York State Police, Albany, N.Y. (Fred Frank).	Univac 418 computer, FASTRAND drum storage, VI-C tape unit 1004, 1004 Univac reader-printer, 1232 optical scanner terminals.	$3,000	$330,000	2	0	4	3	43,000	1966	1966		
State of California Highway Patrol, Sacramento, Calif. (Insp. D. Luethje).	360/30 computer, 7740 switch (2), 1311 disk drives (6), tape drives (5).	$25,000	30,000	0	0	0	0	303,840	1930	1965	(8)	1967–68
Courts:												
Court of Common Pleas, Pittsburgh, Pa.	Electric accounting machine	$272		1	0	2	0	15,264	1954	1963		
District of Columbia Court of General Sessions, Washington, D.C. (D. Meadows).	1440 computer, 1311 disk drives (2).			1	1	0	4	87,000	1958	1964		
Fulton County Data Processing Department, Atlanta, Ga. (J. W. Stephens).	1460 computer, 729 tape drives (4).	$12,122		3	1	17	4	190,500	1958	1964	360/30	1967
The Los Angeles Superior Court, Los Angeles, Calif. (Maureen McPeak).	Electric accounting machine	No charge		2	0	14	0	N.A.	1949	1949	3d generation computer.	1968
Corrections:												
Department of Youth, Sacramento, Calif. (W. J. Dondero).	do	$1,940	18,142	2	2	5	5	83,000	1951	1961	1401 computer, tape drives (5), 360/40—uncertain.	1967
New York State Department of Correction, Gov. Alfred E. Smith Bldg., Albany, N.Y. (A. Barraco).	do[1]	$1,258		3	0	8	0	56,645	1929	1956		

[1] Standard punch-card equipment, including such items as card punches, reproducers, sorters, collators, and accounting machines. All computer systems include such equipment.
[2] To use city computer.
[3] Planned.
[4] To be a city computer with the primary function to serve the Northeastern Ohio Police Information Network.
[5] City computer.
[6] Uses computer in city's water department.
[7] Planning for new facility but undecided on equipment and dates.
[8] Planning to install 2 large computers to replace the 3 now in operation.
N.A. Not applicable.

Table F-4.—Current and Planned Applications of Data Processing by Criminal Justice Agencies

City Police

BALTIMORE CITY POLICE DEPARTMENT

Current applications:
1. Offense statistics for monthly report and "Uniform Crime Reports."
2. Arrest statistics.
3. Radio complaints statistics by location.
4. File of general appearance of suspects.
5. Traffic summons.
6. Statistics on locations of accidents.
7. Personnel records.

Planned applications:
1. Immediate inquiry files on wanted persons, warrants, and stolen automobiles.

BOSTON POLICE DEPARTMENT

Current applications:
1. Monthly report of part I offenses for "Uniform Crime Reports."
2. Arrested persons.
3. Daily recapitulation of offenses and incidents.
4. Location of theft and recovery of stolen cars.
5. Moving traffic violations and recommended dispositions.
6. Amounts earned by officers on offduty paying details.
7. Parking citations issued by location.
8. Index of incidents.
9. Analysis of vehicular accidents.
10. Miscellaneous court statistics for department annual report.
11. Miscellaneous business of the department for department annual report.
12. Ambulance services performed by the department.
13. Age and sex of persons injured or killed in accidents.
14. Notification of fines to out-of-State parking violation defaulters.
15. Officers' training scores on revolver range.
16. Personnel evaluation scores.
17. Citizen alarm box calls and reasons.

Planned applications:
1. Warrant information on wanted persons.
2. Selected stolen property.
3. Firearms identification.
4. Stolen cars and plates and auto parts.
5. Linkage with NCIC.
6. Personnel distribution, car usage, gas and oil studies, payroll, licenses, etc.

Table F-4.—Continued

CLEVELAND POLICE DEPARTMENT

Current applications:
1. Crime reports.
2. Daily traffic court docket report, continued docket, and monthly disposition report.
3. Physical characteristics and modus operandi of arrested persons.
4. Payroll authorization lists.
5. Control of the sicktime, overtime, holidays, and furlough time for each member of the department.
6. Parking citations received and amount paid.

LOS ANGELES COUNTY SHERIFF'S DEPARTMENT

Current applications:
1. Arrests and bookings.
2. Cases handled.
3. Time and location of moving traffic violations.

Planned applications:
1. Jail records.
2. Criminal statistics.

LOS ANGELES POLICE DEPARTMENT

Current applications:
1. Arrests.
2. Crimes.
3. Traffic citations and accidents.
4. Personnel.

Planned applications:
1. Immediate inquiry wanted persons.
2. Immediate inquiry warrants.

OAKLAND POLICE DEPARTMENT

Current applications:
1. Juvenile reporting.
2. Field contact reporting.
3. Complaint dispatch and out-of-service reporting.
4. Offense and arrest reporting.
5. Accident reporting.
6. Traffic citation reporting.
7. Assignment reporting.
8. Nalline test reporting.
9. Miscellaneous reporting.
10. Management control reports.
11. Officer's activity report.
12. Consumed time report.
13. Personnel reports.
14. Talent inventory.
15. Leave-of-absence reporting.
16. Man-days-worked reporting.
17. Personnel duty rosters.

CITY OF PORTLAND BUREAU OF POLICE

Current applications:
1. Offenses reported.
2. Traffic complaints and summons issued.
3. Daily timecards for personnel.
4. Cars and persons involved in reported accidents.
5. Parking tags.
6. Auto registration data by license number.

SEATTLE POLICE DEPARTMENT

Current applications:
1. Crime records.
2. Arrests or citations.
3. Court dispositions.
4. Traffic accidents.
5. Personnel records of employees.
6. Stolen property.
7. Juvenile activity.
8. Moving traffic violations.

Planned application:
1. Allocation of manpower and equipment.

CHICAGO POLICE DEPARTMENT

Current applications:
1. Crime statistics.
2. Operations reports.
3. Arrests.
4. Traffic accident and citation reports.
5. Hot desk reports on stolen autos and wanted persons.
6. Automotive cost accounting.
7. Payroll and personnel statistics.

Planned applications:
1. General index file.
2. Arrest processing.
3. Field reporting.
4. Personnel files.

DETROIT POLICE DEPARTMENT

Current applications:
1. Crime analysis—by precinct, time, day, object of attack, scout car area.
2. Traffic tickets—by ticket number, violation, precinct issued.
3. Arrest analysis—by prosecution, age, sex, color, precinct, etc.
4. Accident analysis—by cause, violation, day, night, etc.
5. Stolen car inquiry—stolen cars by license number, vehicle identification on random access.
6. Modus operandi—trademarks of crime to pick suspect.
7. Women's division report—contacts by crime, precinct, disposition.
8. Youth bureau report—contacts by crime, precinct, disposition.
9. Hot car file—listing by license number of stolen cars.
10. Personnel—name, precinct assigned to, rank.

Planned applications:
1. Traffic warrants.
2. Gun registrations.
3. Serialized property.
4. Personnel, history.
5. Scout car assignments.
6. Answers to radio calls.
7. Police inventory.

FORT WORTH POLICE DEPARTMENT

Current applications:
1. Radio calls.
2. Traffic accidents.
3. Offense reports, clearance and recovery records.
4. Jailed arrestees.
5. Traffic citations.
6. Police personnel list.
7. Police mailing list is kept on IBM cards.
8. Police garage report.
9. Patrol division personnel assignment.
10. Possible addresses in each census tract.

Planned applications:
1. Identification files.
2. Auto registration files.
3. Suspicious person reports.
4. Warrant files.
5. Traffic offender file.

INDIANAPOLIS POLICE DEPARTMENT

Current applications:
1. Records of calls for service and response time, location, and action.
2. Delinquent notices for unpaid traffic violations.

Planned applications:
1. Immediate inquiry for stolen cars and wanted persons.
2. Inventory control.
3. Budget analysis and forecasting.
4. Vehicle fleet maintenance accounting.
5. Modus operandi file.

Table F-4.—Continued

NEW YORK CITY POLICE DEPARTMENT
Current applications: No information.
Planned applications:
1. Computer aided dispatching of radio motor patrol.
2. Vehicle identification immediate inquiry file.
3. Immediate inquiry "phonetic code" name file.
4. Personnel files.
5. Computer assisted fingerprint file searching.
6. Fleet statistics.
7. Crime type, location, date, time, and other data.
8. Computer aided personnel and equipment allocation.

PHOENIX POLICE DEPARTMENT
Current applications:
1. Monthly reports on crime distributions and times spent on calls in different locations.
2. Beat boundaries and patrol distribution based upon the time and location of offenses.
3. Traffic accidents reports by type, frequency, and location.
4. Juvenile criminal activity reports by sex, age, and case disposition.

CITY OF SAN ANTONIO POLICE DEPARTMENT
Current applications:
1. Statistical data of police activity.
2. Records of accountability status, followup activity, and final disposition for traffic (moving violation) arrest tickets.
Planned application:
1. Accounting and disposition of traffic (moving violations) arrests.

ST. LOUIS METROPOLITAN POLICE DEPARTMENT
Current applications:
1. Bench warrant inquiry system.
2. Personnel records.
3. Accident reports.
4. Printouts from mailing list.
5. Owner's name and address, make and model of car accessible by license number.
6. Additional data on cars of special interest.
7. Activities of cars by incident.
8. Census tract and locations data.
9. Field activity accounting of officers.
10. Records of crimes committed, crimes cleared, and unfounded crimes.
11. Financial records.
Planned applications:
1. Inventory accounting.
2. Charge account billing.
3. Resource allocation.
4. Wanted persons.
5. Parking tag accounting.

TUCSON POLICE DEPARTMENT
Current applications:
1. Personnel records.
2. Inventory control file.
3. Impounded vehicle listing.
4. Stolen and recovered property file.
5. Criminal arrest file.
6. Offense classification (crime) file
7. Traffic collision file.
8. Traffic citation file.
9. Police vehicle collision data.

METROPOLITAN POLICE DEPARTMENT, WASHINGTON, D.C.
Current applications:
1. Known offenses statistics.
2. Arrest statistics.
3. Traffic accident reports.

State Police

MICHIGAN DEPARTMENT OF STATE POLICE
Current applications:
1. Fingerprint searching.
2. Traffic accidents.

NEW JERSEY STATE POLICE
Current applications:
1. Fingerprint search.
2. Criminal arrest.
3. Motor vehicle arrests.
4. Motor vehicle accidents.
5. Crime incidents.
6. Summons control.
Planned applications:
1. Personnel records.
2. Troop and station activities.
3. Records and budgetary information.

PENNSYLVANIA STATE POLICE
Current applications:
1. Daily activity reports.
2. Criminal arrest statistics.
3. Traffic accident and enforcement summary.
4. Traffic arrrest statistics by location.

NEW YORK STATE POLICE
Current applications:
1. Message switching for teletype traffic.
2. Stolen car file listing and searching.
3. Distribution of personnel.
4. Personnel time and activity records.
Planned applications:
1. Crime statistics.
2. Traffic summons, records, and statistics.
3. Patrol distribution.
4. Accident location information.
5. Fleet maintenance records.
6. Pistol permit files.

CALIFORNIA STATE POLICE
Current applications:
1. Records showing effect of enforcement action on motor vehicle accident control.
2. Automatic statewide auto theft inquiry system.
3. Statewide statistical information from motor vehicle accidents.
4. Officer daily activity records.

Courts

COURT OF COMMON PLEAS (ALLEGHENY COUNTY, PA.)
Current application:
1. Statistical record of all cases filed or at issue.

DISTRICT OF COLUMBIA COURT OF GENERAL SESSIONS
Current applications:
1. Daily traffic ticket audit.
2. Notices for unpaid traffic tickets.

THE LOS ANGELES SUPERIOR COURT
Current applications:
1. Register of actions or docket page.
2. Index pages.
3. Attorney scheduling.
4. Accounting of payments to court appointed doctors and attorneys.
5. Juvenile traffic records.
6. Index of applications for release on own recognizance.
7. Criminal statistics.
Planned applications:
1. Automatic printing of branch court calendar pages and case abstract reports for department of motor vehicles.

Table F-4.—Continued

THE LOS ANGELES SUPERIOR COURT—Continued
2. Prior record immediate inquiry.
3. Automatic jury selection, testing, notices, payroll, and travel reports.
4. Case following system, similar to recording now done on the register of actions.
5. Automatic processing of court reporters tapes to printed copy and establishment of file for information retrieval.

Corrections

CALIFORNIA DEPARTMENT OF YOUTH
Current application:
1. Inmate histories including background histories, demographic information, records of movements and official actions.
Planned application:
1. Correctional decisions information system.

NEW YORK STATE DEPARTMENT OF CORRECTION
Current applications:
1. Offenses known to police and arrests by police agencies in New York State.
2. Court disposition of arrests.
3. Arrests and court disposition of persons arrested for major offenses.
4. Inmate population statistics.
5. Directory of police agencies in New York State.

INFORMATION SYSTEM FLOW DIAGRAMS

by Ronald A. Finkler

Contents

INTRODUCTION

In designing or revising an information handling system, the system planner must be able to identify those functions and processes which represent either the greatest difficulties, bottlenecks, or inefficiencies, or provide the greatest potential for improvement from either a cost or efficiency point of view. This requires an understanding and description of the way in which information is generated, transmitted, and processed in the system. An accurate description of the system is necessary:

To obtain data on the information flow rates, volumes, processing times, elapsed time intervals, sequences of operations and operating costs.

To provide the foundation and benchmark against which to measure the performance of any proposed new system.

To serve as an experimental model for testing and evaluating changes to the system.

If the operation being analyzed is a complex one, the system planner is faced with the problem of collecting the information in a systematic way so that he is not inundated by a huge assortment of facts and figures. He needs to organize his description of the current operation so that it can be effectively used for system design purposes. One tool that has been useful in the analysis of an information handling system is the system flow diagram. The flow diagram by itself is not sufficient, however. Generally more operational data is needed than can be conveniently shown on a chart or a diagram. Accordingly, a unique approach was developed and programed to assist in analysis effort of the police, the courts, and the correctional systems. This method is described in detail in a separate report.[1]

Briefly, this approach is based on identifying the major functions within the information handling system and the information paths by which information moves from function to function. By "function" we mean those related processes (be they performed by a person, within an office, or by a machine) by which information is originated, processed, filed, presented to decisionmakers, or otherwise utilized. This identifying information is encoded in digital form and serves as the description of the basic structure of the system. Associated with this can be the other parameters of information content, rate, processing time, and delay time. However, in this analysis we were only able to complete a fairly detailed description of the system structure (the flow diagram). This is presented at two levels, by aggregated functions and information paths in this section, and by details of each function in the separate report.[2] The encoded information was used by a computer to draw the information flow charts in the following sections.

These flow charts can serve as a model of the first step necessary in analyzing the information flow in any department, organization, or jurisdiction. To utilize this information, the flow charts must be tailored to represent the specific system being analyzed. With this framework, important questions, such as whether each functioning entity is receiving the information it requires and whether it is receiving unnecessary or redundant information, can be addressed and proper adjustments made to streamline and optimize the information flow. Then specific operational data and statistics can be gathered. The sum total of these are the system requirements and design which may then be presented to appropriate levels of supervision and management for review and approval. They then serve as a basis for detailed system planning, approval, and implementation.

It must be realized that these flow charts are only a tool for the systematic description of complex operating systems and are only as valuable as the competence and un-

[1] "Criminal Justice Information System Flow Diagrams" now in preparation. The report will be available from the Federal Clearinghouse for Scientific and Technical Information of the National Bureau of Standards.

[2] Ibid.

derstanding of the system designer makes them. Insofar as the included flow charts represent reality, they can serve to elucidate the complex information flow in the criminal justice system and serve as an example of one approach to the design of such information systems.

SYSTEM CONVENTION

The following system conventions are used in depicting the information flow in the criminal justice system. The information system was divided into four subsystems: police, courts, corrections, "other" (persons or systems outside the criminal justice system). The functions and information paths are encoded as follows:

	Function	Information path
Police	5---	[1] 0---
Courts	6---	1---
Corrections	7---	2---
Others	9---	3---

[1] On the flow charts the leading zeros are suppressed on the identifying codes for information paths.

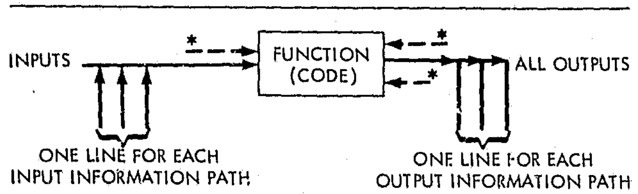
The last three digits of the codes are arbitrarily assigned.

Conventions for function blocks and information flows are shown in figures G–1 and G–2.

POLICE FLOW DIAGRAM

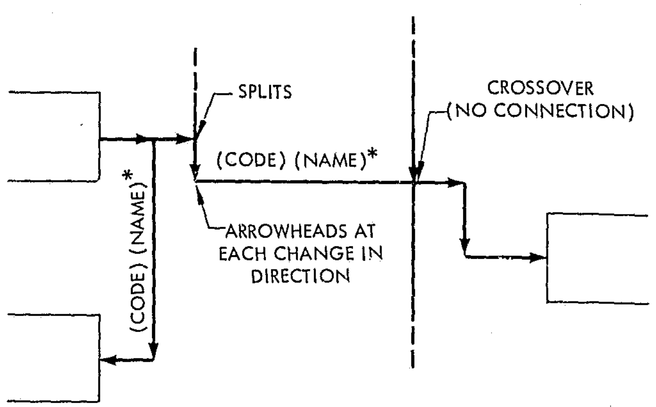
The constraints of time and manpower precluded the possibility of undertaking and completing detailed analysis of the information flow within several major U.S. police departments in order to arrive at a model for the information flow within a typical or generic police department. Instead, the police information flow diagrams were developed on the basis of a prior detailed analysis [3] of a major city police department. The information flow data collected during that extensive analysis were generalized to form the basis for the information flow diagram presented in this section. While it is recognized that there are differences in procedure from one police department to another, it is felt that this generalized information flow diagram represents the major functions in the police system with sufficient accuracy to

FIGURE G-1. CONVENTIONS FOR FUNCTION BLOCKS



*POSSIBLE LOCATIONS OF INPUTS

FIGURE G-2. CONVENTIONS FOR INFORMATION FLOWS



*IDENTIFYING LEGEND SHOWN ABOVE OR TO LEFT OF PATH. LEGEND SHOWN ONLY ONCE FOR EACH CONTINUOUS PATH.

provide at least a starting point for other police information handling systems.

The police flow diagram is presented in figure G–3. The main activities of the police department have been categorized and included in the 22 functions shown in the flow diagram. Each of these functions consists of many nodes which are not shown on this diagram. The police activities have been aggregated into those functions concerned with patrol and traffic, investigation, command and communication, supporting and management activities, and those activities through which the police system interfaces with other systems.

Many important police activities are embodied in the function that has been labeled field officer (patrol and traffic) (5005). This function in the form of field observations, field interviews, preliminary investigations, arrests, and incident reporting is an extremely important source of information for the entire police system. In turn, it is one of the main instruments of the department in deterring crime and apprehending criminals. If he is to carry out this latter mission effectively, then the field officer in turn needs information from a number of other functions as is evidenced by the information paths on the flow diagram.

Command and control is an extremely important aspect of the field activity, and within the constraints of the current system, is maintained through the reporting hierarchy of the patrol supervisor (5006), patrol commander (5007), bureau chiefs and the chief of police (5004). The communications center function (5012) is, of course, vital to the entire field operation. This is particularly true for monitoring patrol activities, allocating resources for routine or emergency needs, and deploying officers for special situations.

Another important function of the police department is the investigative function (5001). Here the flow of

[3] "LAPD Systems Analysis Summary", SDC–LAPD Joint Study Team, Systems Development Corp., Report No. TM(L)–2497, Dec. 31, 1965.

FIGURE G-3. POLICE FLOW DIAGRAM[1]

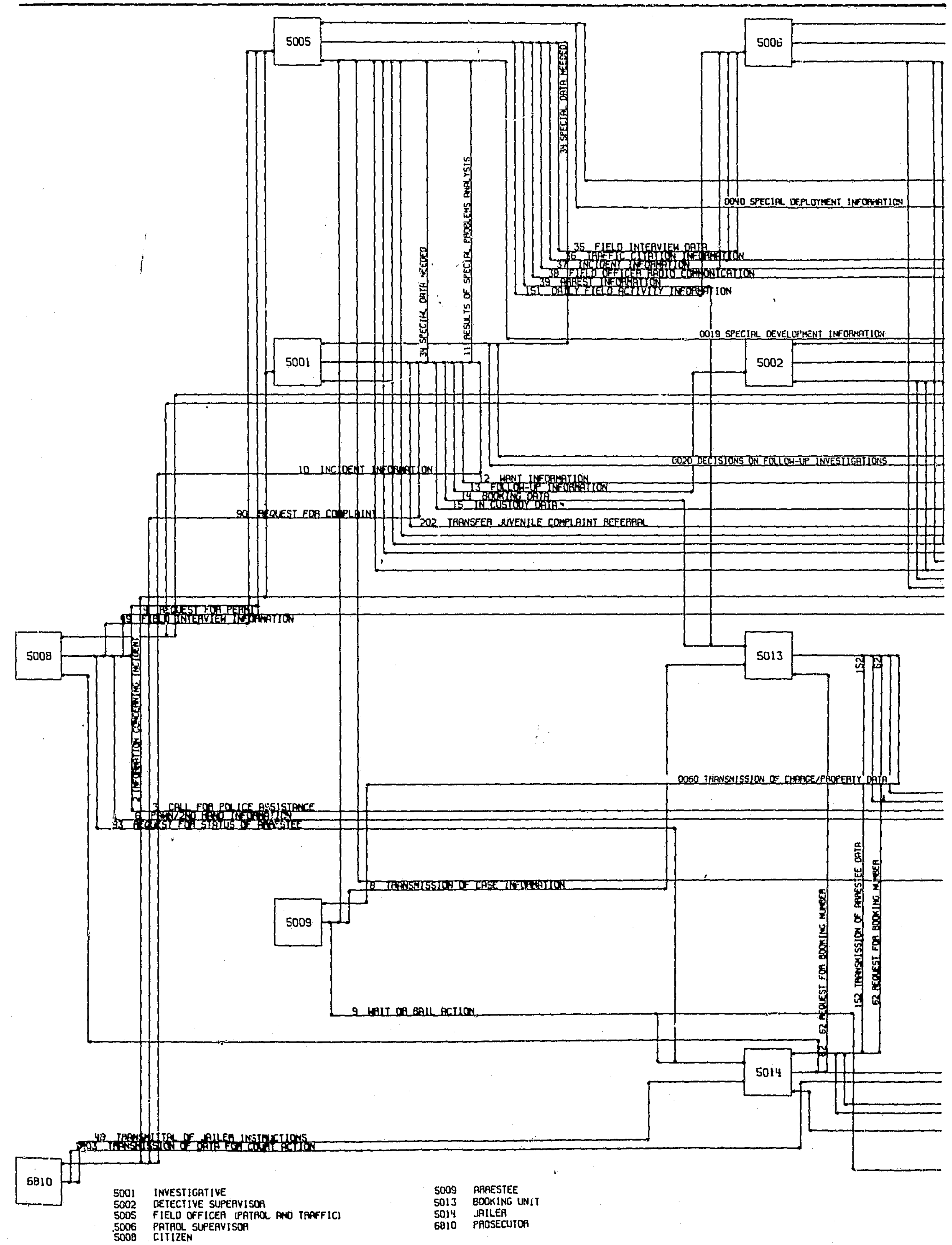


FIGURE 6-3. POLICE FLOW DIAGRAM (Con't)

5003 DETECTIVE COMMANDERS
5007 PATROL COMMANDER
5012 COMMUNICATIONS CENTER
5015 DIVISION RECORDS UNIT
5016 CENTRAL RECORDS UNIT

6001 MUNICIPAL COURT CLERK
6003 MUNICIPAL COURT-PRELIMINARY HEARING
7201 COUNTY PROBATION OFFICE JUVENILE COMPLAINT REVIEW
7213 SUPERVISOR VIOLATION REVIEW

5004 CHIEF OF POLICE AND BUREAU CHIEFS
5017 ANALYTICAL
5018 EXTERNAL AGENCIES
5021 COMMISSION
5022 INTERNAL AFFAIRS

5023 PLANNING STAFF
5024 INTELLIGENCE
5025 TRAINING
5027 ALL POLICE STATIONS
7112 PROBATION DEPARTMENT FIELD OFFICE

7119 FIELD OFFICER VIOLATION REVIEW
7156 FIELD OFFICE, STATE PAROLE VIOLATION REVIEW
7209 SUPERVISOR VIOLATION REVIEW
7224 STATE YOUTH AUTHORITY RECEPTION CENTER
7235 STATE PAROLE SUPERVISOR PAROLE VIOLATION REVIEW

information becomes even more important. This function must rely heavily on information provided to it from the division and central records unit (5015, 5016), but it in turn is also an important contributor of information as a natural product of its investigative activities. The investigative function also has its hierarchical command structure through the investigative supervisor (5002) and commander functions (5003), which are concerned with effectiveness monitoring and control, allocation of resources, and deployment of personnel for special problems.

As indicated, the field officer and investigative functions interact with the citizen (5008), who provides information concerning incidents or requests assistance from the police. Until an arrest occurs, a great deal of the information generated and transmitted in the police system concerns itself with various aspects of the incident. Once an arrest is made, the information generated and transmitted begins to centralize on the arrestee (5009) himself as he proceeds through the booking function (5013) and is jailed, or released on bail or his own recognizance. At this point also, the police system begins to interface with the courts and corrections systems.

The police information flow diagram portrays the processing of information associated primarily with adults. For those incidents associated with juveniles, a special element of the investigative function is involved and at this point the police system interfaces with the juvenile court and the correction agencies (7201).

The supporting functions of the police system are those concerned with analysis, planning and management. The police commissioner function (5021) is concerned with such broad management functions as the formulation of policy and the conduct of special investigations of police department activities. These special investigations are carried out by the internal affairs function (5022). The planning function (5023) supports the chief of police (5004) through long-range planning, budgeting, and resource inventory activities. The analytic function (5017) is concerned with the analysis of incidents to detect patterns of activity which are used for alerting the other elements of the department.

In the normal course of conducting its affairs, the police department must interact with a number of other systems which have not been portrayed in detail, but have been categorized as external agencies (5018) on this flow diagram. These agencies are other local police agencies, State agencies, and Federal agencies. The State agencies typically include such functions as State highway patrols, motor vehicle bureaus, criminal identification bureaus, etc. The Federal agencies include organizations such as the FBI which both collects data from and supplies data to the police department.

COURT FLOW DIAGRAM

The flow of information in the court closely parallels the course of the case as it proceeds through the court system. The information flow diagram presented here in figure G–4 is based on an analysis made of the operation of the criminal courts in a typical county in an Eastern State. Since there are important differences in the procedures and operations of the courts from State to State, this flow diagram is only broadly typical of the operations of the court system.

The flow of information starts with the decision by the prosecutor (6810) to prepare a complaint which identifies the accused and the charge against him. The complaint goes to the municipal court clerk (6001) who generates the municipal court docket and prepares the court calendar. If the accused has been arrested for a misdemeanor, the clerk schedules the municipal trial (6008) and notifies the various parties involved—the accused (6004), his counsel (6010), the prosecutor, and the witnesses (State's 6002, defense 6012)—of the date for the trial. If the accused has been arrested for a felony, the clerk schedules a preliminary hearing (6003).

At the preliminary hearing, the information relating to the case is reviewed and if probable cause is established, the accused is bound over to the grand jury (in those States that use the grand jury system). The prosecutor may conduct an investigation (6014) of his own. If so, the prosecutor's investigative reports plus the earlier information on the case are presented to the grand jury hearing (6018) which is scheduled by the grand jury clerk (6016). If the grand jury review results in a decision to indict, then the indictment, after judicial review (6020), is transmitted to the clerk of the criminal court (6021) who prepares a docket for the case. An arraignment and plea schedule (6022) is prepared, the files are transmitted to the judge and the accused is arraigned (6024). If the accused pleads not guilty, a trial (6028) is necessary and the case must be added to the court calendar (6046), the principals notified, and any required summons issued. If the defendant pleads guilty or is found guilty, he must be sentenced (6030, 6034). At this point the court system interacts with the corrections system in the form of the presentence report which is prepared by the court's probation department (7112).

The sentences can take a number of forms—for example, detention in the county jail or in a State prison, suspension of sentence, or probation. At any of these points, the defendant and the information about him enters the corrections system.

CORRECTIONS FLOW DIAGRAMS

The corrections system flow diagrams present a picture of the flow of information between the various functions required in the corrections areas. For this discussion the corrections system has been divided into adult and juvenile parts. Since the Federal correction system is very similar to the local and State adult corrections system its flow charts have been included in the separate Report.

MUNICIPAL AND COUNTY ADULT CORRECTIONS

As shown in figure G–5, the local prosecutor (6014) may or may not have adequate means via special investigators to obtain sufficient information about the circumstances under which the accused is charged. In either case, he may decide to utilize the services of probation and parole office personnel (7751) to conduct a pretrial deferred prosecution investigation. With leads from the prosecutor's available files on the case, the assigned field officer (7752) obtains information about the defendant's alleged crime and his background through interviews (7753) with the defendant and his attorney (9110), codefendants (9111), his wife and family (9112), the welfare agency (9113), his employers (9114), doctors (9115), religious and civic leaders (9116), and any witnesses, complainants, and victims (9117). The field officer summarizes the interviews and prepares a summary of results in the form of a pretrial investigation report; the interview summaries and one copy of the report go to the probation and parole office (7751) while another copy of the report is transferred to the prosecutor (6014).

The next functional area involves a presentence investigation, usually requested by the municipal (6008) or the felony court judge (6030, 6034). This is initiated by the assignment of a county probation department field officer (7111, 7112) who primarily utilizes the interview technique (7113) to obtain pertinent information concerning the background of the accused from persons acquainted with him and information related to the crime from any available source. Specific requests—a rap sheet from police (5016), a crime report from the prosecutor, and an FBI identification record (5111), if available—are made, and any response information is added to the investigation details. The field officer then makes a summary report and sometimes, when requested, adds his recommendation for sentencing.

Another function involves the temporary evaluation and/or treatment of the accused by the department of mental health. (Fig. G–4, 7110) This action is taken on recommendation by the court. A mental health report is generated and forwarded to the court upon release of the accused from temporary detention.

Probation (7114) is a corrections area procedure initiated by appropriate court order. The order, the terms of probation and the presentence report are forwarded to the assigned probation field office supervisor (7115). The supervisor conducts periodic interviews with the probationer (9123), recording information in his field book and issuing periodic probation reports which go to the probation department. Any information obtained from the probationer, the police, or the prosecutor indicating possible violation of probation is reviewed by the field office supervisor (7119) and, if serious enough, submitted to the probation department (7116) for a decision on dismissal or court referral. On referral, the court with jurisdiction in the case holds a violation hearing (6113, 6114) and either dismisses charges or issues a detention order. Appropriate notices go to the supervisor and the probation department file.

If the sentence involves short term detention, a detention order accompanies the sentence to the local detention facility (7117). Here the duration of detention varies from days and weeks in municipal jail or short-term city institutions to weeks and months in county jails, camps, or farms.

STATE ADULT CORRECTIONS

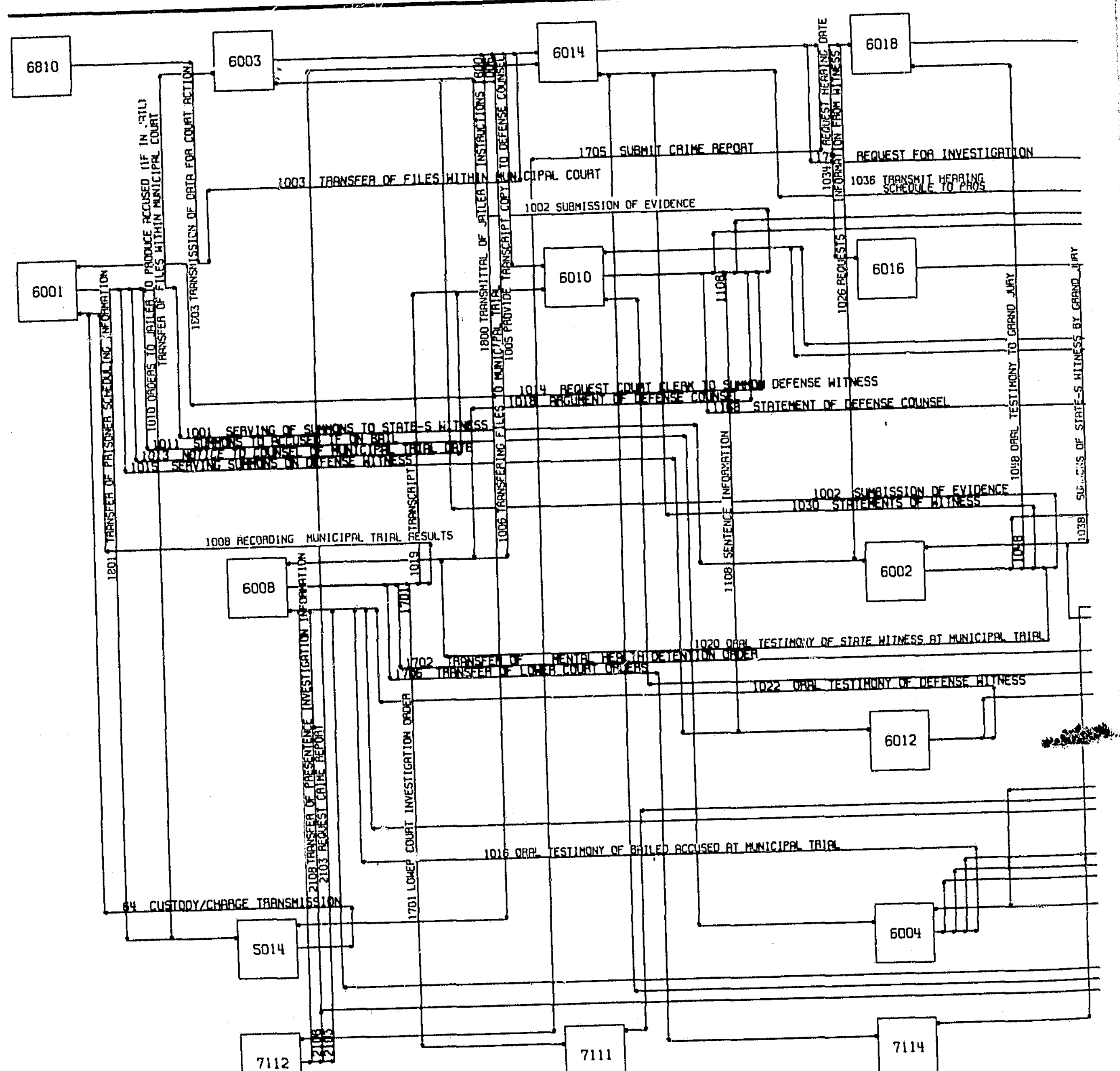
As shown in figure G–6, a sentence for State detention is given by the court (6034) in more serious cases where confinement duration of at least 1 year is called for. Upon issuance of such a sentence, the court's detention notice and presentence report accompany the offender to the State institution reception center (7118) for reception processing. This processing includes the solicitation of specific information about the individual's background and about his current attitudes via questionnaire forms to the defendant and his attorney (9140), his employers, teachers, family (9141) and other State and Federal institutions and agencies (9142) that may have information about him. Based on all the available information on the offender, a decision is reached on the appropriate State institution to be used for his confinement.

Upon receipt of reception center advice, including detention terms and the inmate's record, an institution classification committee selects (7141) the appropriate program from among those available within the assigned institution based on security requirements and rehabilitative goals. An assigned institution program supervisor (7142) monitors the inmate's progress, performs counseling (7143), and prepares periodic assessment reports, which are regularly reviewed by a reclassification committee. Based on supervisor recommendations, security or program requirement reconsiderations, or expiration of specified periods of detention time, a decision is reached on reclassification (7144) of the inmate. Alternatives include no change in status, transfer to another program in the institution (7146), transfer to another State institution (7145), submission of a parole plan to the State parole board (7147), or release upon completion of sentence.

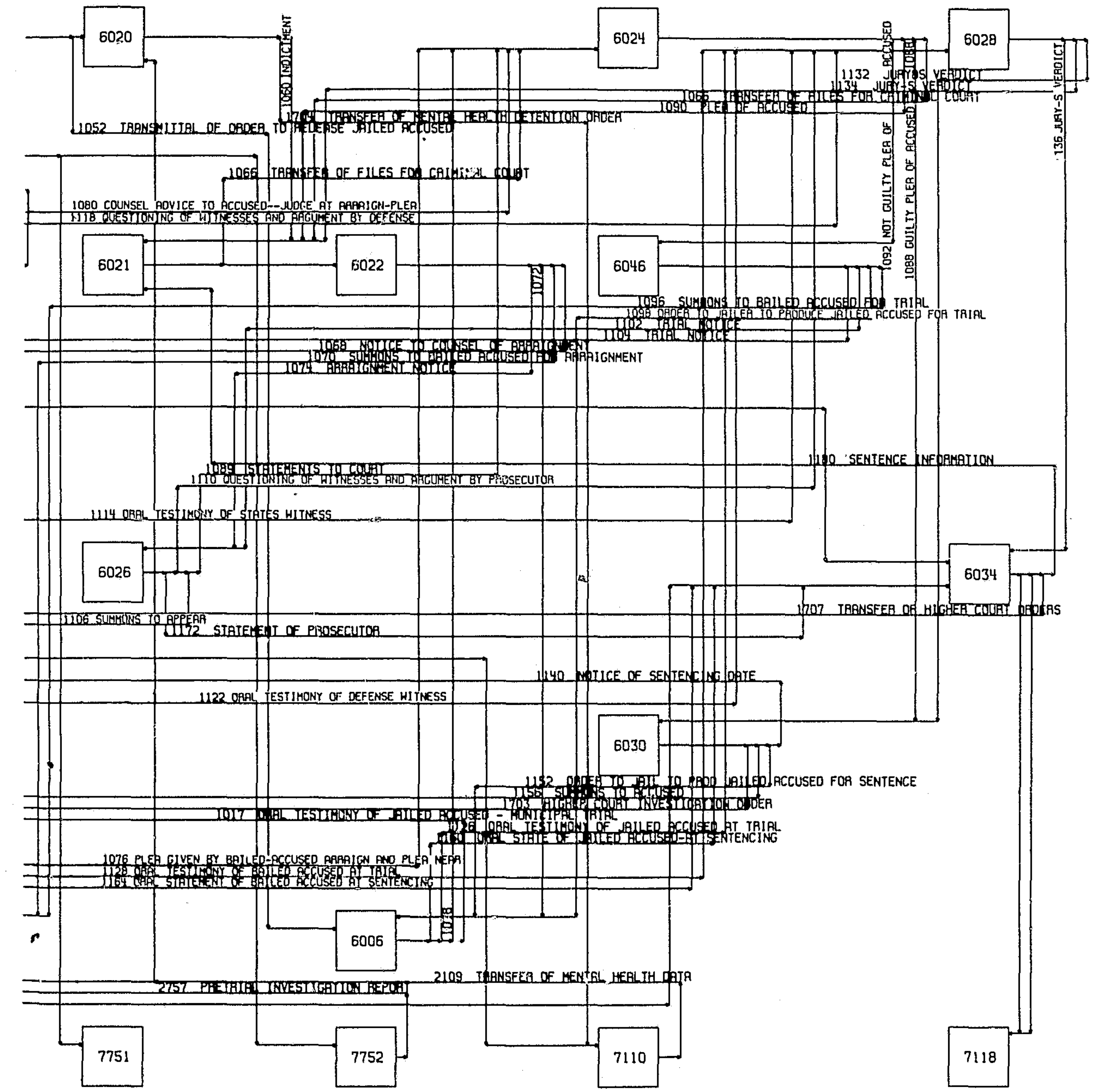
The State parole board, which receives the parole plan and available assessment reports, reviews the plan and either rejects it or orders a preparole investigation (7148) to augment existing information for subsequent acceptability review. The investigation is conducted by a State parole field officer (7149) who usually interviews (7150) intended sponsors (9146), and potential school (9145) and/or employer (9144). Interview details are used as the basis of a preparole investigation summary report; details are retained in the State parole office investigation file and the summary report is transferred to the parole board for its acceptability review (7151).

Prior to a parole decision, the board may require psychiatric treatment (7154) for the inmate at the outpatient psychiatric clinic. A treatment order for temporary

FIGURE 6-4. COURT FLOW DIAGRAM

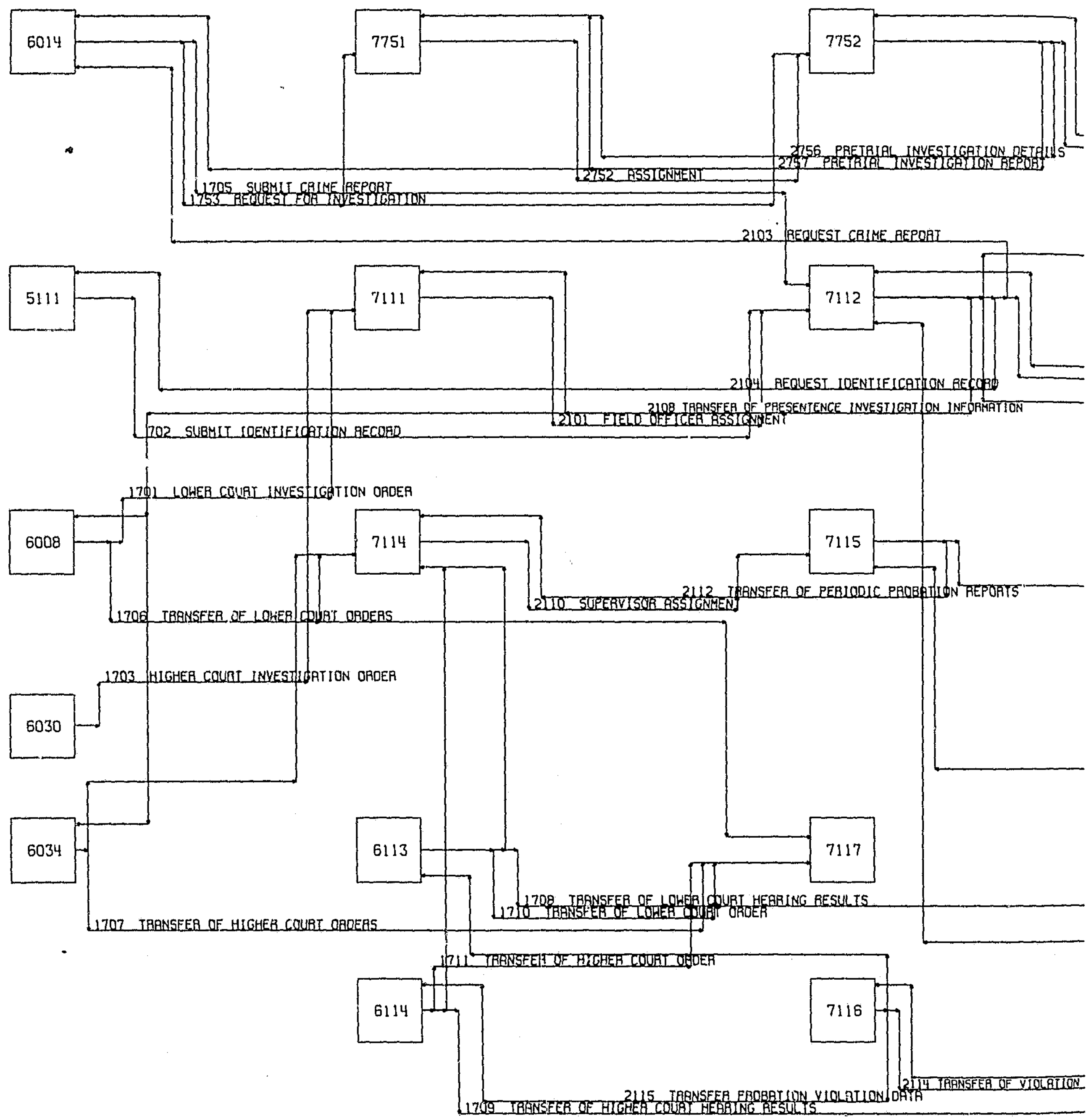


5014	JAILER
6001	MUNICIPAL COURT CLERK
6002	STATES WITNESSES
6003	MUNICIPAL COURT-PRELIMINARY HEARING
6004	ACCUSED ON BAIL
6008	MUNICIPAL TRIAL (MISDEMEANOR)
6010	DEFENSE COUNSEL
6012	DEFENSE WITNESS
6014	PROSECUTOR-S INVESTIGATION
6016	GJ HEARING SCHEDULING
6018	GRAND JURY HEARING
6810	PROSECUTOR
7111	COUNTY PROBATION DEPARTMENT
7112	PROBATION DEPARTMENT FIELD OFFICE
7114	PROBATION ASSIGNMENT DEPARTMENT

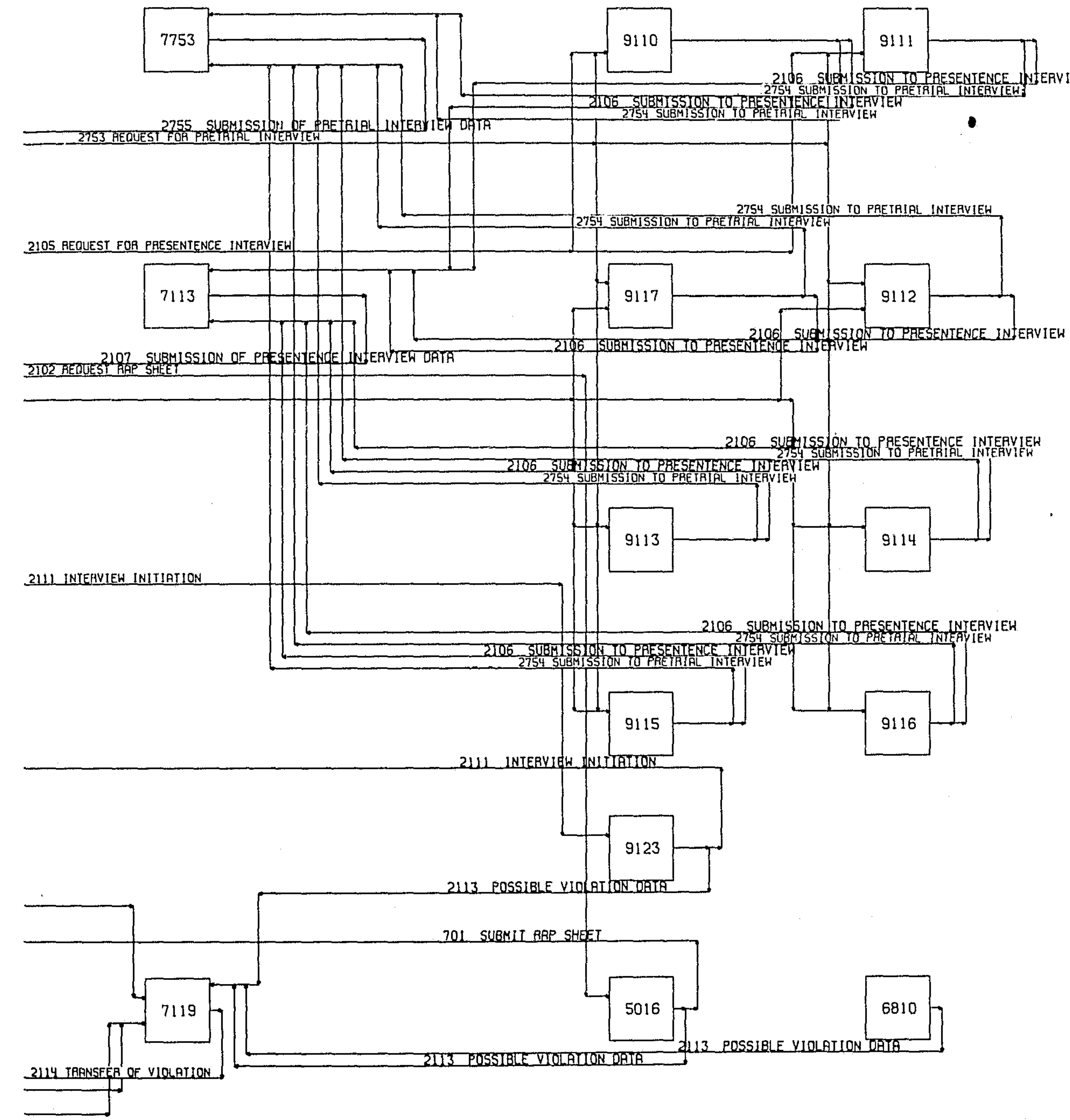


6006	COUNTY JAIL
6020	JUDICIAL PREVIEW OF INDICTMENT
6021	DOCKETING
6022	A AND P SCHEDULING
6024	ARRAIGNMENT AND PLEADING
6026	PROSECUTORS PROSECUTIVE EFFORT
6028	CRIMINAL COURT TRIAL OF FELONY
6030	CRIMINAL COURT SENTENCE SCHEDULING
6034	CRIMINAL COURT SENTENCING
6046	CRIMINAL COURT TRIAL SCHEDULING
7110	DEPARTMENT OF MENTAL HEALTH DETENTION
7118	STATE INSTITUTION RECEPTION PROCESSING
7751	PROBATION AND PAROLE OFFICE
7752	FIELD OFFICE INVESTIGATION

FIGURE G-5. MUNICIPAL AND COUNTY ADULT CORRECTIONS FLOW DIAGRAM

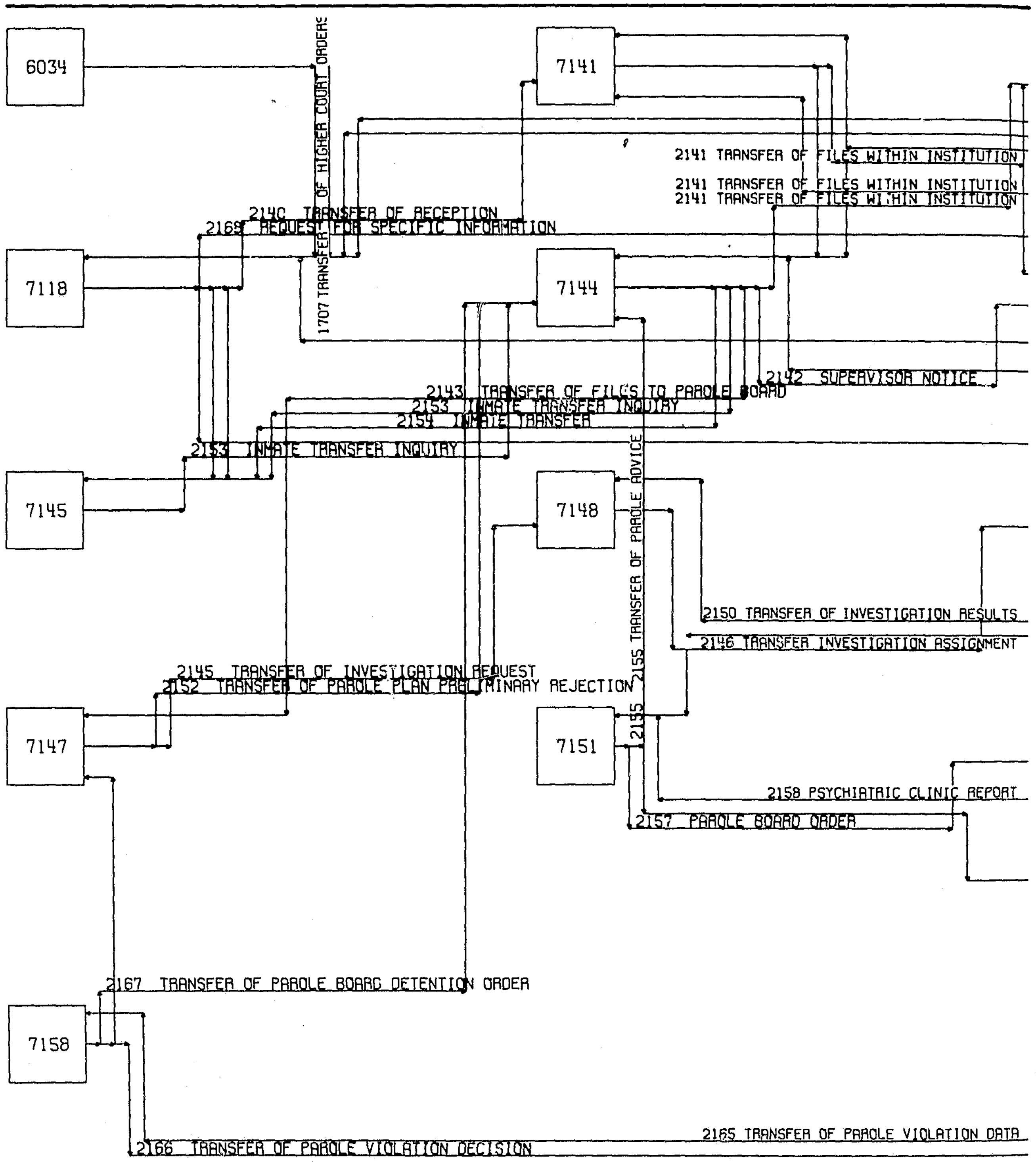


5111 MARSHAL TO FBI
6008 MUNICIPAL TRIAL (MISDEMEANOR)
6014 PROSECUTOR-S INVESTIGATION
6030 CRIMINAL COURT SENTENCE SCHEDULING
6034 CRIMINAL COURT SENTENCING
6113 LOWER COURT VIOLATION HEARING
6114 HIGHER COURT VIOLATION HEARING
7111 COUNTY PROBATION DEPARTMENT
7112 PROBATION DEPARTMENT FIELD OFFICE
7114 PROBATION ASSIGNMENT DEPARTMENT
7115 FIELD OFFICER SUPERVISOR
7116 PROBATION DEPARTMENT VIOLATION REVIEW
7117 LOCAL DETENTION
7751 PROBATION AND PAROLE OFFICE
7752 FIELD OFFICE INVESTIGATION

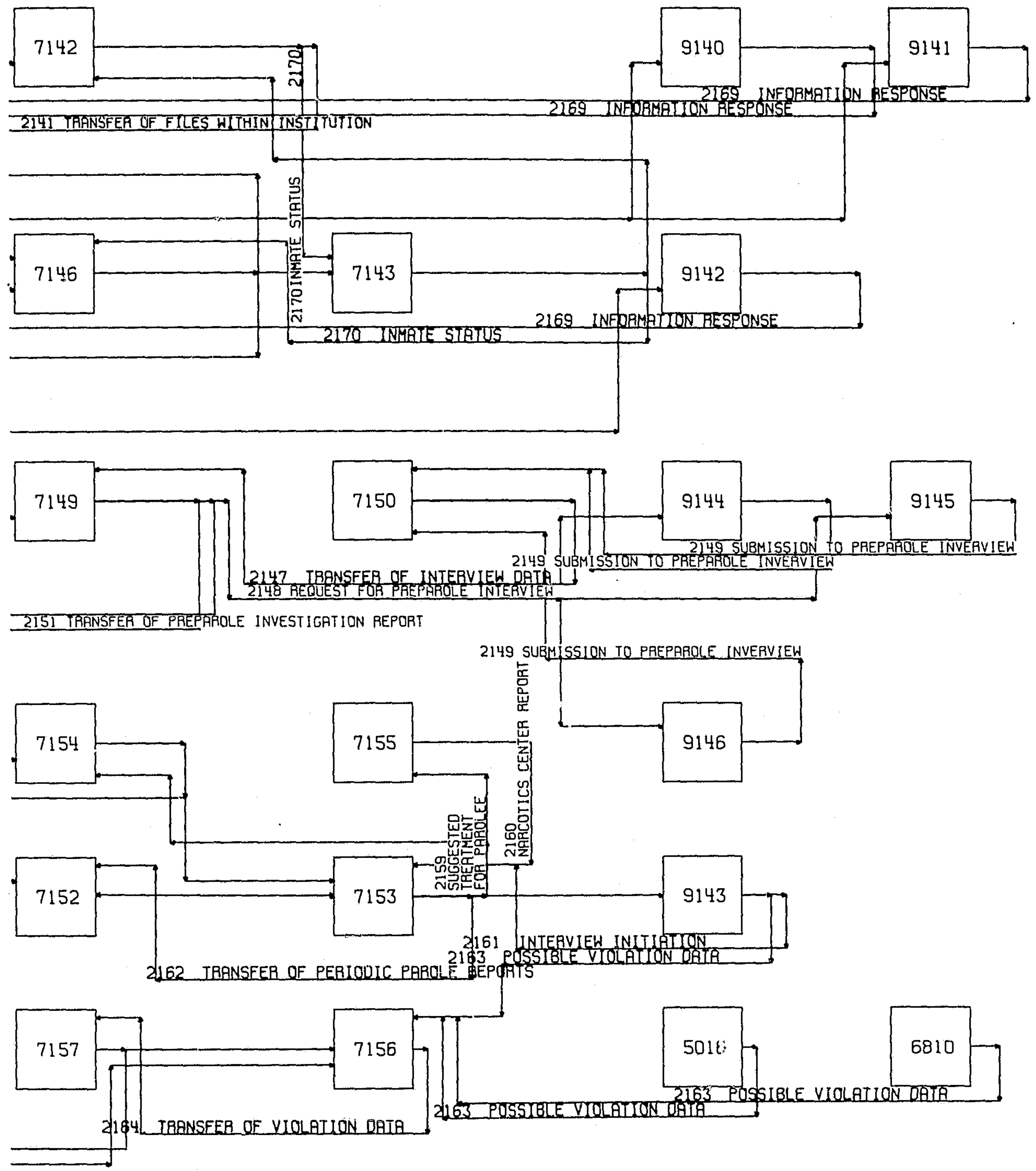


5016 CENTRAL RECORDS UNIT
6810 PROSECUTOR
7113 PROBATION FIELD OFFICER INTERVIEWS
7119 FIELD OFFICER VIOLATION REVIEW
7753 FIELD OFFICE INTERVIEWS
9110 DEFENDENT AND ATTORNEY
9111 CODEFENDENT
9112 WIFE AND FAMILY
9113 WELFARE AGENCY
9114 EMPLOYERS
9115 DOCTORS
9116 RELIGIOUS AND CIVIC LEADERS
9117 WITNESSES, COMPLAINANTS AND VICTIMS
9123 PROBATIONER

FIGURE 6-6. STATE ADULT CORRECTIONS FLOW DIAGRAM



6034 CRIMINAL COURT SENTENCING
7118 STATE INSTITUTION RECEPTION PROCESSING
7141 INSTITUTION CLASSIFICATION PROCEDURE
7144 INSTITUTION RECLASSIFICATION PROCEDURE
7145 OTHER STATE INSTITUTION
7147 STATE PAROLE BOARD PLAN REVIEW
7148 STATE PAROLE OFFICE INVESTIGATION
7151 PAROLE BOARD PLAN ACCEPTABILITY REVIEW
7158 STATE PAROLE BOARD VIOLATION HEARING



5016 CENTRAL RECORDS UNIT
6810 PROSECUTOR
7142 INSTITUTION PROGRAM SUPERVISOR (A)
7143 INMATE COUNSELING
7146 INSTITUTION PROGRAM SUPERVISOR (B)
7149 STATE PAROLE FIELD OFFICER INVESTIGATION
7150 PAROLE FIELD OFFICER INTERVIEWS
7152 STATE PAROLE OFFICE SUPERVISOR ASSIGNMENT
7153 STATE PAROLE FIELD OFFICER SUPERVISION
7154 OUTPATIENT PSYCHIATRIC CLINIC TREATMENT
7155 STATE NARCOTICS CENTER TREATMENT
7156 /FIELD OFFICE, STATE PAROLE VIOLATION REVIEW
7157 STATE PAROLE OFFICE VIOLATION REVIEW
9140 DEFENDANT AND ATTORNEY
9141 EMPLOYERS, TEACHERS, FAMILIES, ETC
9142 OTHER STATE AND FEDERAL INSTITUTIONS AND AGENCIES
9143 PAROLEE
9144 POTENTIAL EMPLOYER
9145 POTENTIAL SCHOOL
9146 PLANNED SPONSOR FAMILY

detention is issued to the clinic and a treatment report is returned upon termination of this temporary detention.

The State parole board accepts or rejects the parole plan; appropriate notice goes to the institution reclassification committee and, if accepted, parole advice from the board is transferred to the State parole office, where a parole supervisor is assigned (7152). The parole supervisor (7153) initiates periodic interviews with the parolee (9143), recording results in his fieldbook and submitting periodic parole reports to the State parole office.

During the period of time that the parole supervisor has responsibility for the parolee, it may happen that the supervisor would feel the need for the parolee to get special treatment. If so, he may arrange for temporary detention of the parolee with either the outpatient psychiatric clinic (7154) or the State narcotics center (7155). A treatment request would be submitted upon admission and an appropriate treatment report would go to the supervisor upon return of the individual to parole status.

If any alleged parole violation information is received by the parole supervisor (7156) from any source, such as the parolee, the police (5016) or the prosecutor (6810), he forwards the violation report to the State parole office if he considers it serious enough. A review by the parole office (7157) may result in either no further action or the transfer of violation data to the State parole board. A hearing (7158) by the board will result in dismissal of violation charges or the transfer of detention notice to the appropriate institution. In either case, the decision notice is forwarded to the supervisor.

COUNTY JUVENILE CORRECTIONS

As shown in figure G–7 the county probation office (7201) can receive referrals on juvenile suspects from municipal courts (6201), from citizens complaints (9201), or from community agencies (9202). Complaint petitions may also come from police as a result of booking (5016) or preliminary investigation functions (5001). An initial, but incomplete, file on the juvenile is likely to be received from municipal court or police sources. The probation office usually initiates a prepetition investigation. The assignment notice and incomplete juvenile file go to the investigating officer (7202), who conducts interviews (7203) for obtaining information on the juvenile's background and on the circumstances of the charges. Summaries are made by the officers based on interviews with the juvenile (9203), his parents (9204), his doctors (9208), religious and civic leaders (9209), welfare agencies (9205), complainants (9206), and any employer (9207) who may have hired him for any period of time. A comprehensive summary report of investigation results is then prepared by the officer and submitted for action and filed (7205).

The county probation office (7204) reviews all collected information on the juvenile case and acts on the complaint by either dismissing the case or referring it to the juvenile court (6202). Upon referral, the juvenile court judge reviews the case, sometimes discussing it with a probation office official.

At the earliest possible time, the probation office prepares a petition (7206) for a hearing on the case in juvenile court (6203). If found guilty, the juvenile is subject to one of several handling alternatives based on a court decision (6204). He could be put on probation in nonward status or as a ward of the court. As a ward of the court, he may also be directed to one of several available county programs (7217). Another possibility is that a State detention order will be issued which will assign the juvenile to the State youth authority (fig. G–6, 7224). The court may decide that evaluation and/or treatment by the department of mental health (7214) is desirable for the juvenile; in this case, a temporary detention order is forwarded to the department and, upon termination of the detention, a mental health report is transferred to the court for a subsequent case handling decision.

If the juvenile is put on nonward probation, the county probation office assigns a probation supervisor (7207) to the juvenile. The supervisor conducts periodic interviews (7208) with the youth (9203) and his parents (9204). Reports prepared from these interviews are forwarded to the county probation office file. Any incident data coming from the juvenile, his parents, or the police (5016) which indicates a potential violation of probation is reviewed (7209) by the supervisor. He may pass it on to the probation office (7210), and if serious enough, a juvenile court hearing (6205) will be set. Results of the hearing may change the probation terms or the juvenile may be put under a different program.

If the juvenile is put on ward probation status, he is subject to the same probation procedure (7211, 7212) as if he were on nonward probation with one exception. A court official is directly involved in any alleged violation review (6206, 7213) and decides what action must be taken, if any.

On a recurring basis, the court probation office solicits applications from potential foster homes via recruiting publicity. Applications are reviewed and either accepted or rejected (7215, 7216). Data pertinent to acceptable foster homes is maintained in the county probation office file (7205) for subsequent reference.

If the juvenile is recommended for one of the several county programs, the appropriate program and the determination of its availability is considered by the juvenile court (7217). Concurrences on the selected program are sought from the youth, his parents (9204), the probation office (7221) and from either the foster home (7222) or the private institution (7223). With positive concurrence on a specific program from those affected, a decision is reached by the court whereby the juvenile is put under supervision in a county camp (7218), a foster home (7219) or a private institution (7220). Periodic reports on the youth's progress in the assigned program are submitted to an appointed court official for review (6208). The court official can also decide on any requested transfer from one program to another (6207).

STATE JUVENILE CORRECTIONS

If the juvenile offense is serious enough to warrant State detention, his file accompanies him to the State youth authority reception center (7224), as shown in figure G–8. Regardless of the information about the juvenile already available from the county probation office file (7205), the reception center initiates requests for specific information via questionnaires to various sources, such as, the juvenile (9203), his parents (9204), teachers and school officials (9217), the social worker (9211) and the police (5016). Information sought includes the juvenile's identity and description, probation reports, social worker reports, police and/or court records, and community school reports. Desired clinical evaluation data includes social and environmental history, psychological and psychiatric status, intelligence and education, violence potential and medical history.

With access to this information, the authority is able to decide the most appropriate rehabilitative program. The juvenile may be ordered to a State detention camp (7225), physical rehabilitation institution (7226), or a correctional educational institution (7227). Prior to his transfer to one of these establishments, or during his study at one of these, it may be decided that the youth requires an evaluation and/or treatment by the department of mental health (7214). Here, he is temporarily detained for examination and a mental health report is prepared. At each of the three State institutions just mentioned, the youth receives appropriate supervision. Periodic assessment reports are prepared, and he may be transferred from one to another of these institutions.

Among other points of review in the juvenile's periodic assessment is that of parole consideration. Parole recommendation and the juvenile file are submitted to the State youth authority board upon decision by institution supervisors to recommend parole. A preliminary review is made by the State youth authority board (7228). The board may reject parole at this time, or it may request a pre-parole investigation by the State parole division.

Assignment (7229) is made to the State investigating officer to determine the details (7230) of an appropriate parole situation. The officer interviews (7231) the planned sponsor (9216), usually a family, and potential school (9210) or employer (9215) where the juvenile's activities are to be centered. Details and summaries of these interviews are submitted to the State parole division, where a specific parole plan is prepared (7232).

The State youth authority board reviews the specific parole plan. An adverse decision results in rejection notices being transmitted to the institution supervising the juvenile and the parole plan designer in the State parole division. Board approval results in an acceptance notice going to the institution presently supervising the juvenile and the board official who must assign a State parole supervisor (7233) for the youth.

Parole involves periodic interviews by the supervisor (7234) with the juvenile and his sponsor (9213). Results are recorded in the supervisor's fieldbook and reports are prepared from information in the fieldbook. Any data involving possible violation of parole may come to the supervisor from the juvenile, his sponsor, his school (9214), his employer (9212), or from the police (5016). The supervisor considers the seriousness of the alleged violation (7235) and may dismiss it as insignificant, decide to require the youth's supervision in a youth detention center (7236), or refer the matter to the State youth authority board. Return to parole from the youth detention center would be ordered by the supervisor if reports from the center show that return to parole is warranted.

Parole violation review by the State youth authority board (7237) may result in dismissal of violation charges or the youth's return to a State institution. The latter decision causes a parole revocation notice to be transferred to the appropriate institution.

ACKNOWLEDGEMENTS

The task of gathering the data which served as a basis of these information flow diagrams fell to many very competent people familiar with information systems and its relation to the criminal justice system. Without their unstinting effort this task could not have been accomplished. They include:

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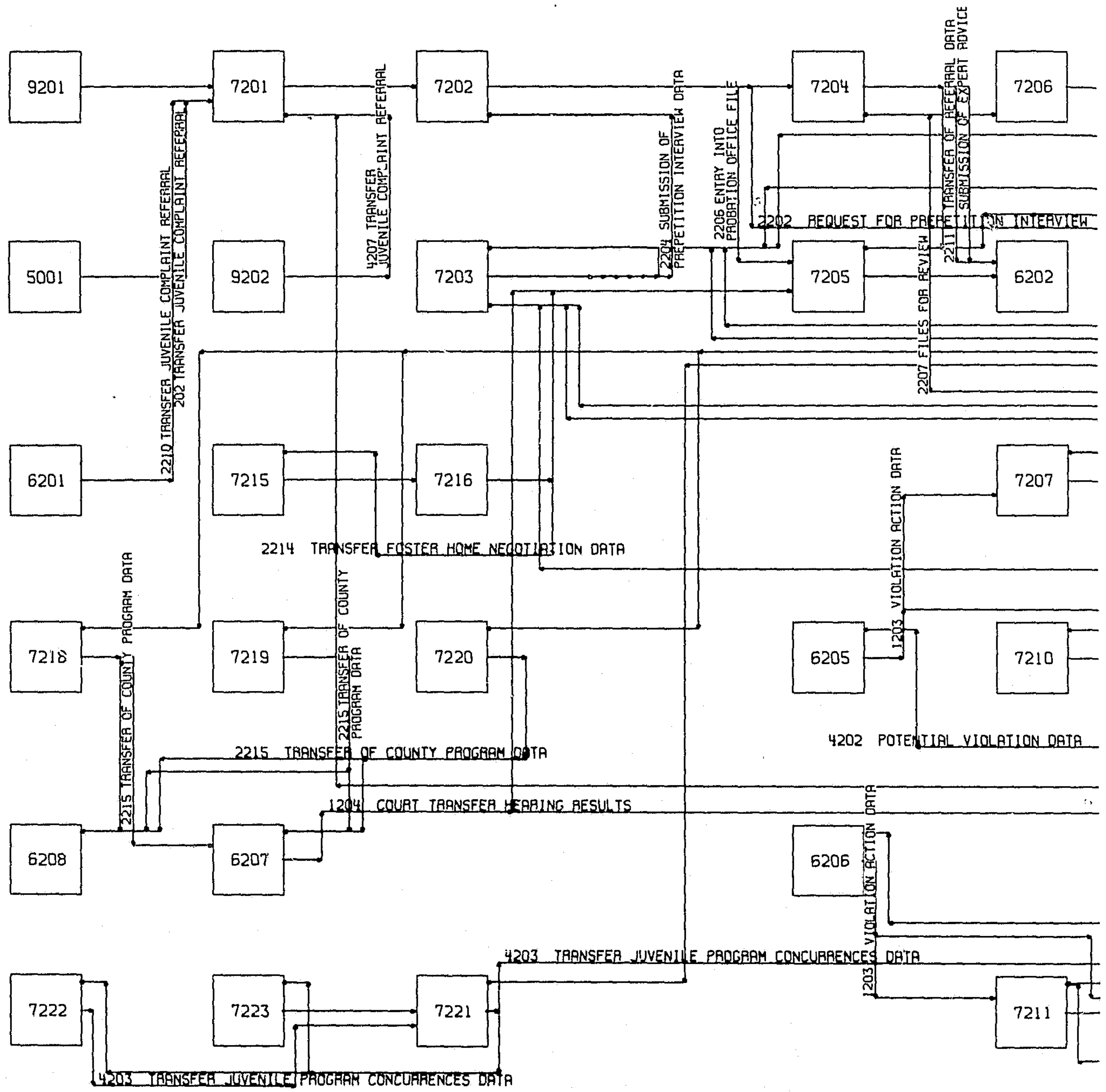
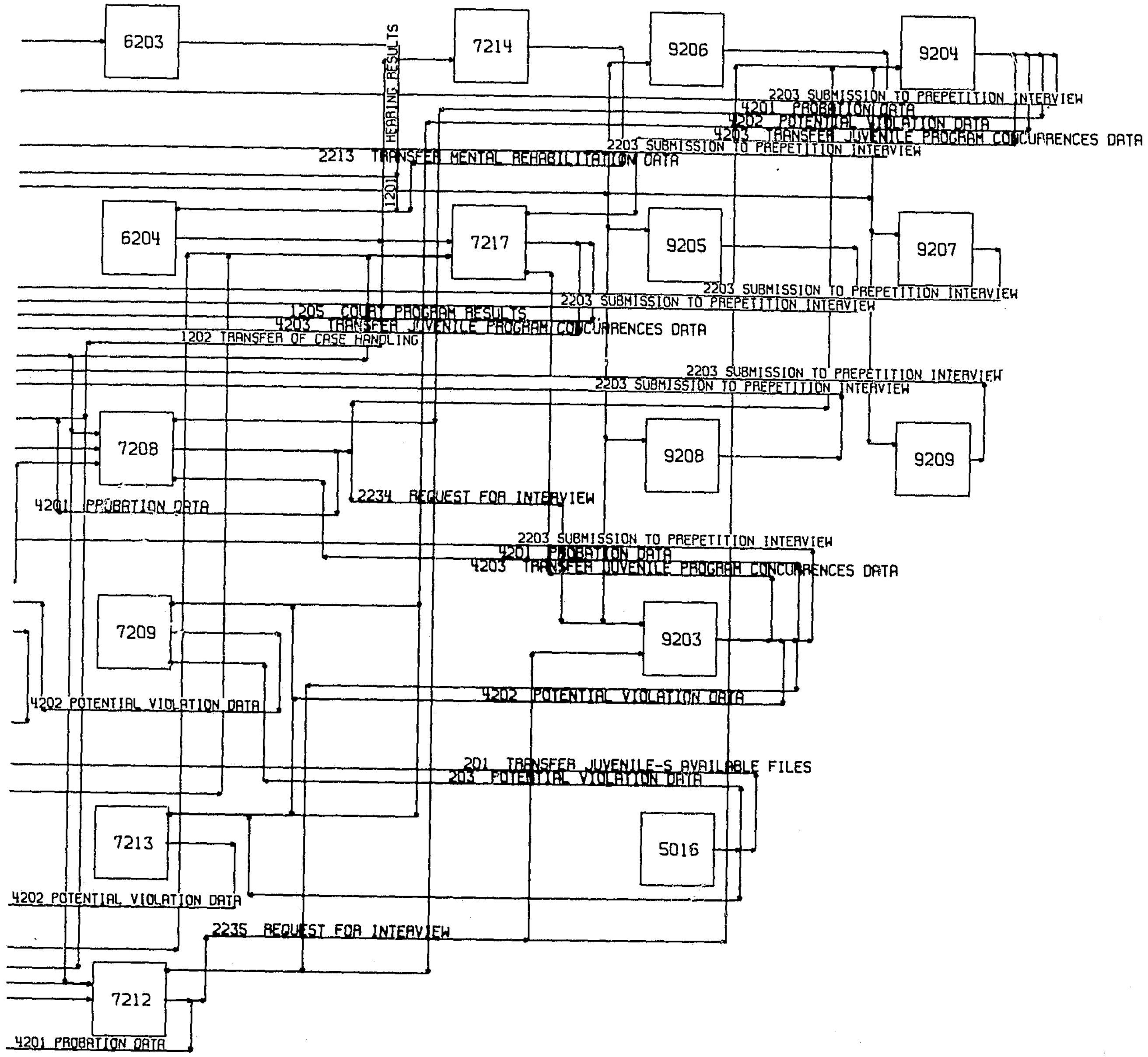
FIGURE G-7. COUNTY JUVENILE CORRECTIONS FLOW DIAGRAM

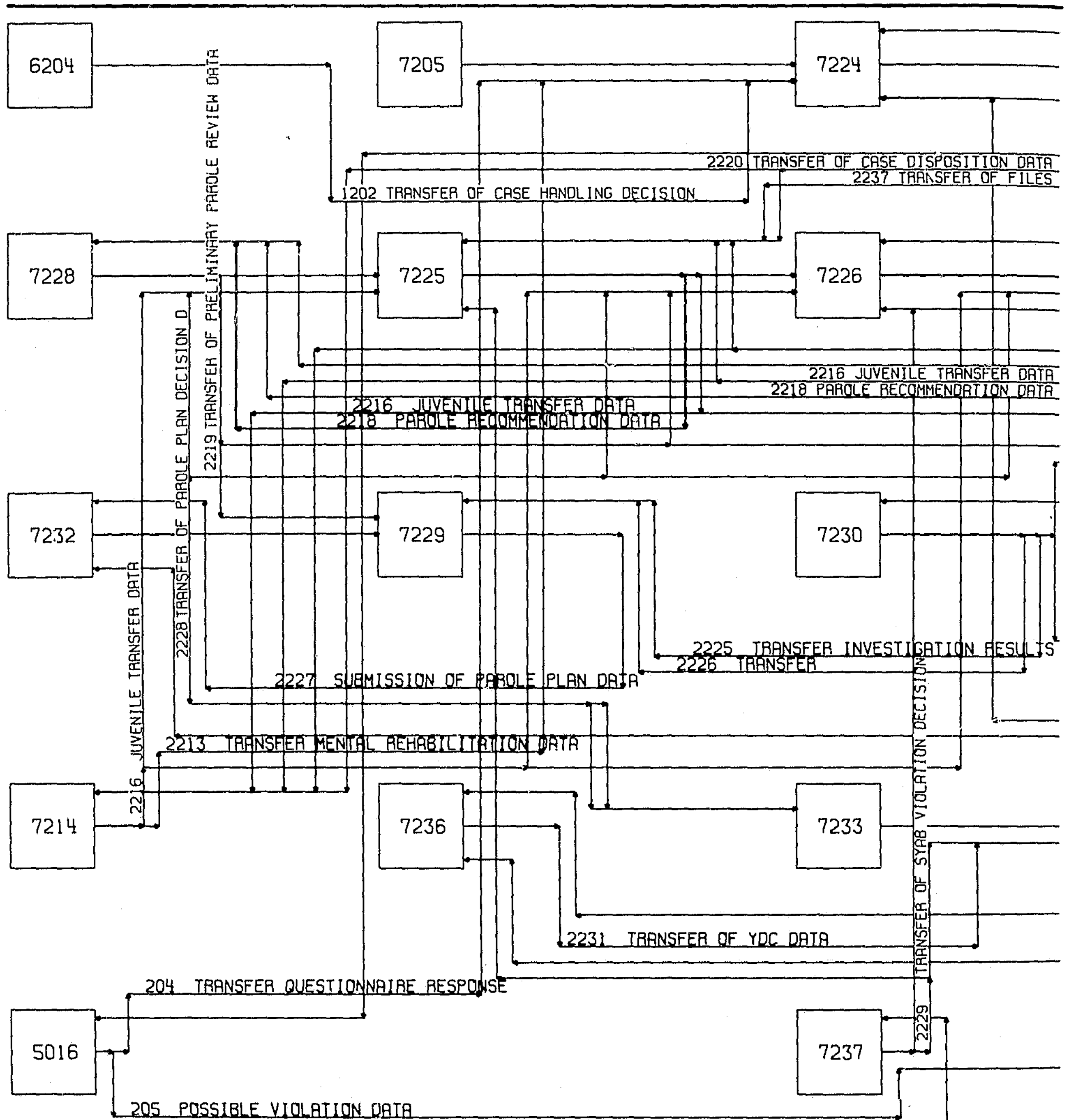


5001	INVESTIGATIVE	7207	PROBATION OFFICER ASSIGNMENT
6201	ADULT COURT JUVENILE REFERRAL	7210	PROBATION OFFICE VIOLATION REVIEW
6202	JUVENILE COURT COMPLAINT NOTICE RECEIPT	7211	PROBATION OFFICER ASSIGNMENT
6205	JUVENILE COURT VIOLATION HEARING	7215	FOSTER HOME QUALIFICATION
6206	COURT OFFICIAL VIOLATION HEARING	7216	FOSTER HOME REGISTRATION
6207	COURT OFFICIAL TRANSFER HEARING	7218	COUNTY CAMP SUPERVISION
6208	COURT OFFICIAL REPORTS REVIEW	7219	FOSTER HOME SUPERVISION
7201	COUNTY PROBATION OFFICE JUVENILE COMPLAINT REVIEW	7220	PRIVATE INSTITUTION SUPERVISION
7202	ASSIGNED OFFICER INVESTIGATION	7221	PROBATION OFFICE CONCURRENCE REVIEW
7203	OFFICER INTERVIEWS	7222	FOSTER HOME CONCURRENCE
7204	COUNTY PROBATION OFFICE ACTION ON COMPLAINT	7223	PRIVATE INSTITUTION CONCURRENCE
7205	COUNTY PROBATION OFFICE	9201	CITIZEN COMPLAINT REFERRAL
7206	PROBATION OFFICE PETITION ACTION	9202	COMMUNITY AGENCY COMPLAINT REFERRAL

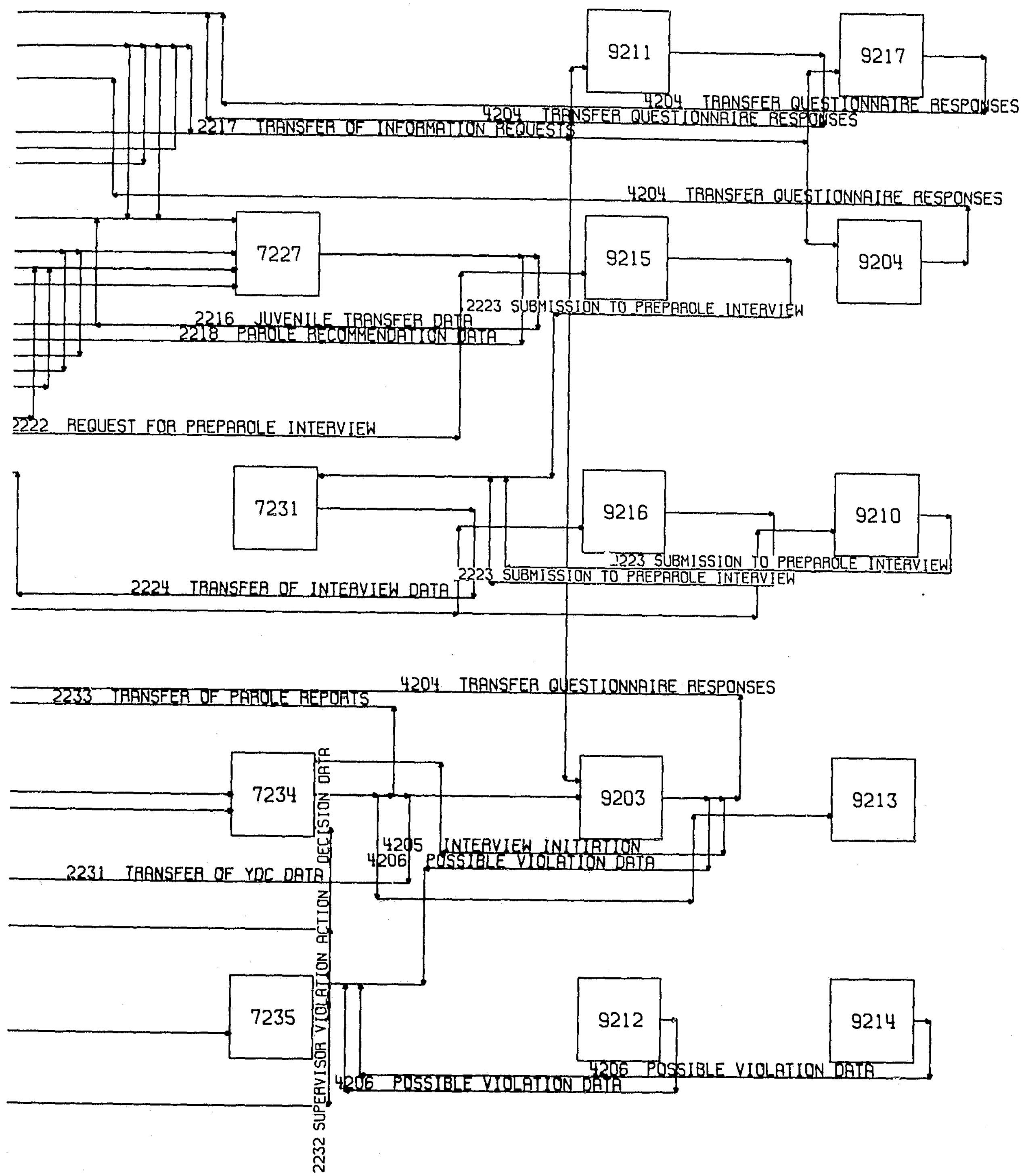


5016	CENTRAL RECORDS UNIT	7217	JUVENILE COURT COUNTY PROGRAM CONSIDERATION
6203	JUVENILE COURT CASE HEARING	9203	JUVENILE
6204	JUVENILE COURT CASE HANDLING DECISION	9204	PARENTS
7208	PROBATION SUPERVISION	9205	WELFARE AGENCY
7209	SUPERVISOR VIOLATION REVIEW	9206	COMPLAINANTS
7212	PROBATION SUPERVISION	9207	EMPLOYERS
7213	SUPERVISOR VIOLATION REVIEW	9208	DOCTORS
7214	DEPT OF MENTAL HEALTH DENTENTION	9209	RELIGIOUS AND CIVIC LEADERS

FIGURE C-8. STATE JUVENILE CORRECTIONS FLOW DIAGRAM



5016 CENTRAL RECORDS UNIT
6204 JUVENILE COURT CASE HANDLING DECISION
7205 COUNTY PROBATION OFFICE
7214 DEPT OF MENTAL HEALTH DENTENTION
7224 STATE YOUTH AUTHORITY RECEPTION CENTER
7225 STATE DETENTION CAMP SUPERVISION
7226 PHYSICAL REHABILITATION INSTITUTIONS SUPERVISION
7228 STATE YOUTH AUTHORITY BOARD PRELIMINARY PAROLE REVIEW
7229 STATE PAROLE DIVISION INVESTIGATION ASSIGNMENT
7230 STATE OFFICER INVESTIGATION
7232 STATE YOUTH AUTHORITY BOARD PAROLE PLAN REVIEW
7233 STATE YOUTH AUTHORITY BOARD SUPERVISOR ASSIGNMENT
7236 YOUTH DETENTION CENTRAL SUPERVISION
7237 SYAB (STATE YOUTH AUTHORITY BOARD) PAROLE VIOLATION REVIEW



7227 CORRECTIONAL EDUCATIONAL INSTITUTIONS SUPERVISION
7231 STATE OFFICER INTERVIEWS
7234 STATE PAROLE SUPERVISION
7235 STATE PAROLE SUPERVISOR PAROLE VIOLATION REVIEW
9203 JUVENILE
9204 PARENTS
9210 POTENTIAL SCHOOL
9211 SOCIAL WORKER
9212 EMPLOYER
9213 SPONSOR
9214 SCHOOL
9215 POTENTIAL EMPLOYER
9216 PLANNED SPONSOR (FAMILY)
9217 TEACHERS, SCHOOLS

ANALYSIS OF THE COSTS OF A CENTRALIZED VERSUS DECENTRALIZED NATIONAL INQUIRY SYSTEM

by Ronald Finkler

Contents

INTRODUCTION

Modern computer technology makes possible a national inquiry system by which local law enforcement agencies can obtain information from a national file on stolen automobiles, stolen identifiable property, guns, and wanted persons. An analysis has been conducted to investigate several alternative system configurations to determine which one involves the least incremental system cost. The three major cost factors considered are the cost of computation, the cost of computer storage, and the cost of communication. The cost and workload estimates are based on analyses being carried out for the FBI by the Institute of Telecommunication Sciences and Aeronomy of the Environmental Science Services Administration of the Department of Commerce. The information is preliminary since their final report has not yet been written.

Three national system models were chosen for this analysis. The first is a centralized system where all functions are performed at a single centralized location. For this model, two location alternatives were considered: the minimum cost location and Washington, D.C. The second model was a national system maintained in two locations to minimize communication costs. Here again, two alternatives were considered: a minimum cost pair of locations, and a pair of locations where one was constrained to be Washington, D.C. and the second positioned so as to minimize costs. It is assumed that each location has a complete copy of the national file. The third model was a completely distributed system where each State had to interrogate all States in order to search the national file completely.

The analysis of the three system models was essentially divided into two parts, one related to the problem of stolen autos and the second related to the problem of stolen identifiable property, guns, and wanted persons. This differentiation was made because inquiries of the stolen auto file, based on license plate information, have a specific State location to which they can be addressed. This is not the case for inquiries of the other files. A second consideration is that about 45 percent of stolen autos are recovered within 24 hours and about 70 percent are recovered within the jurisdiction of theft, with a high probability that a large fraction of the remainder are recovered in immediately surrounding jurisdictions. In the case of wanted property, guns, and persons, the probability of inquiry also decreases rapidly with distance from the point of theft or crime. More data are needed to assess the value of national integration of the inquiry system. Eventually, a judgment must be made weighing the loss in nonrecovery or nonapprehension as a result of a police jurisdiction not having ready access to a complete national file against the cost of maintaining such a file. This cost analysis will attempt at least to place cost on some aspects of these various alternatives.

All the systems studied here, including the decentralized one, were nationally integrated in the sense that a complete national file is made available to each inquiry station. It is still possible to have separate, nonintegrated State or regional systems, accepting the penalty of losing track of people or property crossing the regional boundary.

THE COST MODEL

It is assumed in the cost model that each State has implemented in its State capital a State-wide inquiry system to serve its other needs. From the resulting workload, only the following portions are treated in this analysis:

- Stolen autos;
- Stolen identifiable property over $1,000 in value;
- Wanted persons whom the State is willing to extradite from anywhere in the United States.

This workload consists of:

- Entries, either the generation or deletion of a record in a file of reports of thefts or wants;
- Inquiries, the processing and searching of these files.

After processing each *entry*, other than those relating to stolen autos, the State will pass on the entry to the national system for the generation or deletion of a file available to other State systems. Similarly, after processing each *inquiry*, other than those relating to stolen autos, the State will pass on the inquiry for search of the national file. This is necessary since a given item or person may appear in either or both the State and national files even with the nonoverlapping definitions of the files.

For the stolen auto file, two cases are considered:

Case 1.—Entries related to the theft of an auto are sent to the national system after 24 hours and the entry is deleted from the State file. Inquiries related to this file must be processed both in the State system and sent on to the national system since the time of theft would not be known.

Case 2.—Entries are still sent on to the national system after 24 hours but they are not deleted from the State system. Inquiries based on "own State" license plate information are processed only in the State system; inquiries based on out-of-State license plates or on autos without plates are sent on to the national system without prior State processing.

The incremental cost equation for computer time in the *jth* State for both cases is given by:

$$C_{1j}=(E_j\tau_{CE}+I_j\tau_{CI})C_c$$

where:

E_j=Total number of entries/month generated in the *jth* State.

I_j=Total number of inquiries/month generated in the *jth* State.

τ_{CE}=Computer time necessary to process one entry.

τ_{CI}=Computer time necessary to process one inquiry.

C_c=Cost per unit computer time.

For this analysis, we assume that:

$$\tau_{CE}=\tau_{CI}=1 \text{ second}$$

Therefore,

$$C_{1j}=(E_j+I_j)C_c$$

where:

C_c=Cost per second of computer time.

The incremental cost equation for storage in the *jth* State is given by:

Case 1:

$$C_{21j}=S_{1j}C_s$$

Case 2:

$$C_{22j}=S_{2j}C_s$$

where:

S_{1j}=File storage size for Case 1 in millions of characters for the *jth* State.

S_{2j}=Same for Case 2.

C_s=Storage cost per million characters.

It is assumed in the cost model that communications between the State and national systems will be provided on a dedicated line basis by GSA utilizing Telpak lines at standard GSA rates. This cost per line is of the form:

$$C_t+C_ld$$

where:

C_t=terminal cost/line/month.

C_l=line cost/mile/line/month.

d=toll line distance of the line as given by A.T. & T.

The number of lines required between the *jth* State and the national system for the two cases considered are given by:

Case 1:

$$L_{1j}=[4K((E_{oj}+\tfrac{1}{2}E_{aj})\tau_E+I_j\tau_I)]+1$$

Case 2:

$$L_{2j}=[4K((E_{oj}+\tfrac{1}{2}E_{aj})\tau_E+(I_{oj}+.05I_{aj})\tau_I)]+1$$

where:

$[x]$=Largest integer less than the argument x.

E_{oj}=Total number of entries/month for files other than stolen auto generated in the *jth* State.

E_{aj}=Same for stolen auto file.

I_{oj}=Total number of inquiries/month for files other than stolen auto generated in the *jth* State.

I_{aj}=Same for stolen auto file.

τ_E=Communication time for transmission of an entry.

τ_I=Communication time for the transmission of an inquiry and reception of a reply.

K=Conversion factor.

The numerical factors contained in these equations are based on the following considerations:

☐ The factor 4 in communication capacity is used to compensate for peak loads caused by the variability of the communication load over the day. It is used to insure a high probability of a line being free when required with minimum delay.[1]

☐ The factor ½ applied to E_{aj} is based on data indicating that approximately 50 percent of stolen autos are recovered within 24 hours, therefore only one-half of the entries generated within the State would be passed on to the national system.

☐ The factor .05 applied to I_{aj} in Case 2 is based on the assumption that when a State is maintaining its own stolen auto file, approximately 5 percent of the inquiries would be on out-of-State autos or autos without license plates.

Three national system models were chosen for this analysis. The first is a centralized system where all functions are performed at a single centralized location. For this model, two alternatives were considered: The minimum cost location and Washington, D.C. The second model was a national system in two locations to minimize communication costs. Here again, two alternatives were considered: A minimum cost pair of locations and a pair of locations where one was constrained to be Washington, D.C., and the second positioned so as to minimize costs. It is assumed that each location has a complete copy of the national file. The third model was a completely distributed system where each State had to interrogate all States in order to completely search the national file.

CENTRALIZED NATIONAL SYSTEM

For the centralized system (fig. H–1), the computer-time cost equations for the two cases are given by:

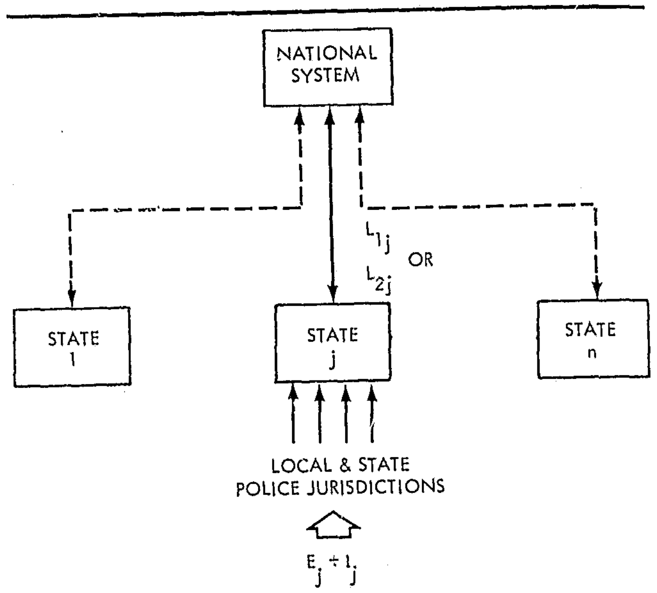
Case 1:

$$C_{31}=\sum_j((E_{oj}+\tfrac{1}{2}E_{aj})\tau_{CE}+I_j\tau_{CI})C_C$$

Case 2:

$$C_{32}=\sum_j((E_{oj}+\tfrac{1}{2}E_{aj})\tau_{CE}+(I_{oj}+.05I_{aj})\tau_{CI})C_c$$

FIGURE H-1. CENTRALIZED NATIONAL SYSTEM



where the variables are defined as before and if the assumption that $\tau_{CE}=\tau_{CI}=1$ second is made as before:

Case 1:

$$C_{31}=\sum_j(E_{oj}+\tfrac{1}{2}E_{aj}+I_j)C_c$$

Case 2:

$$C_{32}=\sum_j(E_{oj}+\tfrac{1}{2}E_{aj}+I_{oj}+.05I_{aj})C_c$$

The cost equation for storage for both cases is given by:

$$C_4=S_3C_S$$

where:

S_3=National file storage size in millions of characters.

C_S=as before.

TWO-LOCATION NATIONAL SYSTEM

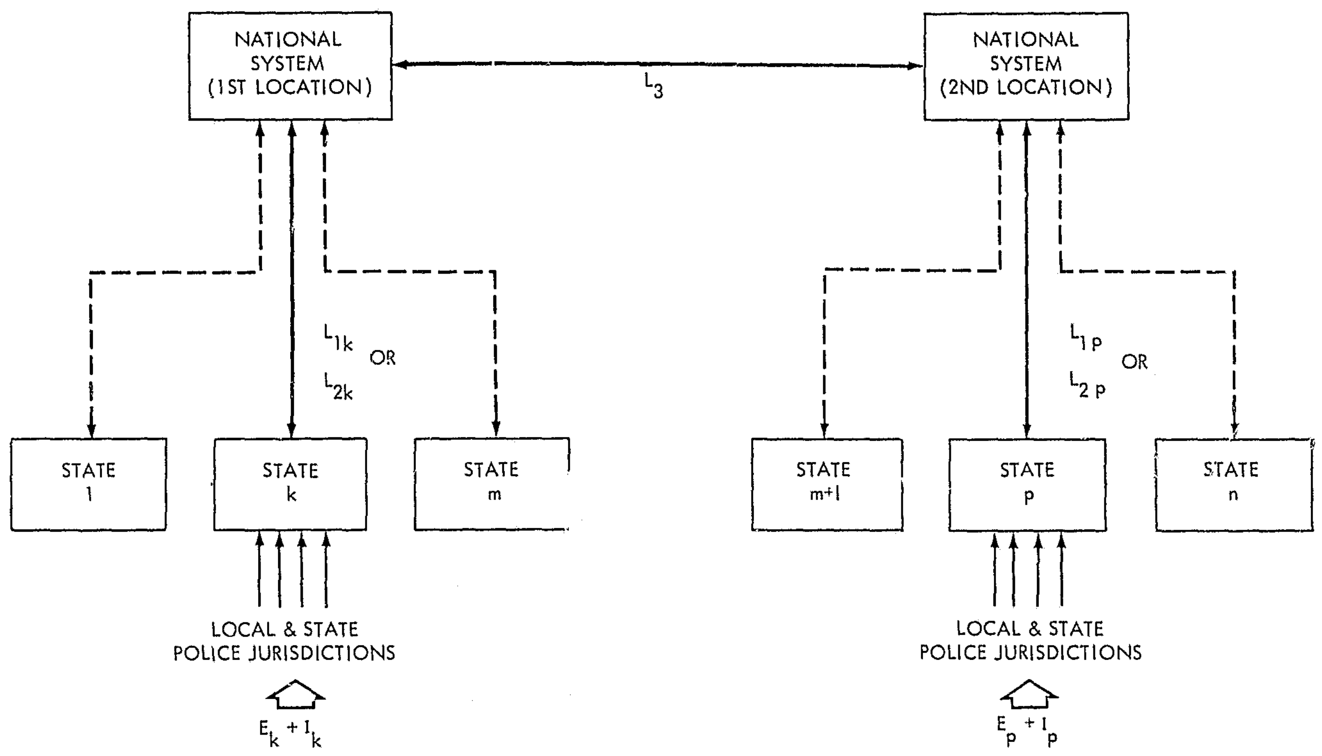
For the two-location national system (fig. H–2) the computer time costs equations for the two cases (again assuming that $\tau_{CE}=\tau_{CI}=1$ second) are given by:

Case 1 (first location):

$$C'=\sum_k(E_{ok}+\tfrac{1}{2}E_{ak}+I_k)C_c$$

[1] Letter report from Donald R. Macken, Institute for Telecommunication Sciences & Aeronomy, to J. J. Daunt, FBI; Subject: Fifth Progress Report in a series on the National Crime Information Center Telecommunications Study, ITSA Project No. V52362420; Sept. 6, 1966.

FIGURE H-2. TWO LOCATION NATIONAL SYSTEM



where k is the index of the States serviced by the first location.

Case 1 (second location):

$$C''=\sum_l(E_{ol}+\tfrac{1}{2}E_{al}+I_l)C_c$$

where l is the index of the States serviced by the second location.

However, the sum is just the centralized computer time cost.

$$C_{31}=C'+C''$$

Similarly for Case 2, the computer time cost is the same C_{32}.

In addition to this cost, there is the further cost of each location updating the other in order that each maintains a complete national file. This cost for both cases is given by:

$$C_5=\sum_k(E_{ok}+\tfrac{1}{2}E_{ak})C_c+\sum_l(E_{ol}+\tfrac{1}{2}E_{al})C_c$$
$$=\sum_j(E_{oj}+\tfrac{1}{2}E_{aj})C_c$$

The cost for storage at each location for both cases is C_4, the national file storage cost, or a total of $2C_4$.

Additional communication lines are also required between the two locations, given by:

$$L_3=\left[4K\sum_k E_k\tau_E\right]+1+\left[4K\sum_l E_l\tau_E\right]+1$$

DISTRIBUTED SYSTEM

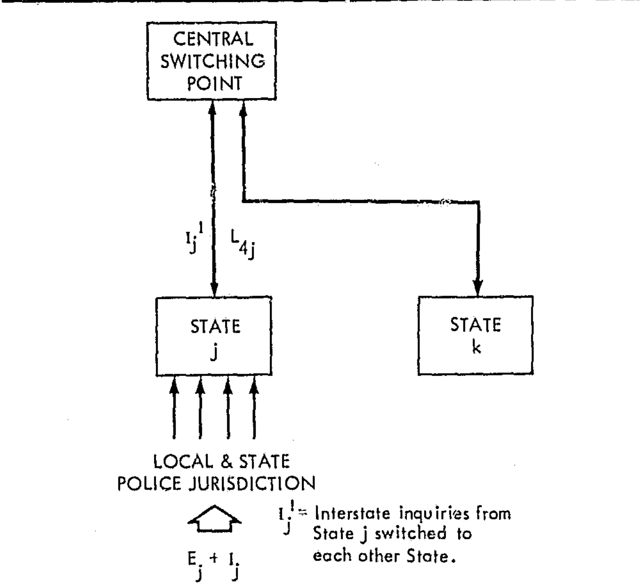
For a fully distributed system (fig. H–3), the system configuration assumes complete State files maintained in each State and a centralized communications switching point for distributing the inquiries from each State to all the other States. The total computer time cost equation (neglecting the cost of the central switching point) is given by:

$$C_6=\sum_j(E_j+I_j)C'_c+\sum_j\Big(\sum_k(I_{ok}+.05I_{ak})-(I_{oj}+.05I_{aj})\Big)C_c$$

The total storage cost equation is given by:

$$C_{22}=\sum_j C_{22j}$$

FIGURE H-3. DISTRIBUTED SYSTEM



The number of communication lines required between the jth State and the central switching point is given by:

$$L_{4j}=\left[4K\{I_{oj}+.05I_{aj}\}\tau_j\right]+1$$
$$+\left[4K\{\sum_k(I_{ok}+.05I_{ok})-(I_{oj}+.05I_{aj})\}\tau_j\right]+1$$

ESTIMATION OF NUMBER OF ENTRIES AND INQUIRIES

The following is an abstract of the Fifth Progress Report in the series on the National Crime Information Center Telecommunications Study, ITSA Project Number V52362420. Their analysis estimates the workload requirements on the NCIC system for 1970. The number of offenses for that period was estimated in two different ways. The first based on a straight-line extrapolation of the offenses as a function of population at the current crime rate, and the second based on extrapolation of the crime rate. In table H–1, of the two numbers given for each State, the upper number is the straight-line extrapolation and the lower number is based on the crime rate extrapolation.

The first consideration which must be given to any telecommunications network design problem is the data rate. For the NCIC study, crime data published in "Uniform Crime Reports," an annual publication published by the FBI, have been used as the numerical data foundation. In addition, two real time systems, smaller in scope but similar to the NCIC in operation, are now functioning in the United States. These are in California and St. Louis, Mo. The experience gained from these two automated systems has been used in predicting system usage.

The State of California has had more experience with the use of real time computerized law enforcement data than any similar organization in the Nation, and on a wider scale, since all levels of State and local government are involved in the California program. The California statistics, on the usage of the system have been checked against similar statistics from other users and found to correlate very closely in all cases. With these things in mind, the 1965 California data were selected as the prime basis for usage predictions for the NCIC network.

In table H–1 the first and second columns are the 1970 predictions for number of stolen autos and the number of all other offenses, respectively. Of the stolen autos, 50 percent are recovered within 24 hours and will not be reported to NCIC. Eighty-nine percent of the remaining 50 percent, or 44.5 percent of the total, are eventually recovered and their entries will need to be deleted. Together the entries and deletions (called "entries" in the table) amount to the equivalent of 94.5 percent of the total number of stolen autos. This gives a monthly rate of approximately 8 percent of the total number of stolen cars per year.

California in 1965 had 27,000 entries per month, exclusive of autos, or 324,000 entries per year. For the same period, there were 410,000 offenses in California for the same group of crimes. These figures give 0.80 as many entries as offenses for the year, or approximately 0.07 times as many entries per month as offenses per year. Thus:

Offenses (per year) × 0.07 = interrogations per month for crimes other than auto theft.

In 1965, California had an average of 40 interrogations per hour of their Auto-Statis center. This amounts to 345,600 interrogations per year. During the same period 81,773 autos were reported stolen. Therefore, during the year, there were 4.21 interrogations per stolen auto. Reduced to a monthly basis, this is 0.35 interrogation per month, per stolen car, per year.

Stolen cars (per year) × 0.35 = interrogations per month

Interrogations of NCIC, for offenses other than auto theft, probably should be based on the number of arrests, since arrested persons are likely to be the ones checked against the information at NCIC. From "Uniform Crime Reports, 1965," a population of 134 million had 4,955,000 arrests. Deleting the

Table H-1.—Estimated Entries and Interrogations to the Central Inquiry File in 1970[1]

	Offenses/year		Entries/month		Interrogations/month		Total		Communication time (minutes/hour)		
	Auto	Others	Auto	Others	Auto	Others	Entries	Interrogations	Entries	Interrogations	Total
United States	469,000 427,547	3,058,000 3,447 070	51,900 47,876	214,100 240,160	227,200 254,764	382,250 431,000	266,000 298,036	609,450 685,764	126.00 138.40	423.00 476.00	549.00 614.40
Alabama	4,800 5,550	44,300 50,000	380 440	3,100 3,500	1,670 1,940	5,540 6,250	3,480 3,940	7,210 8,190	1.61 1.82	5.00 5.68	6.61 7.50
Arizona	6,150 6,930	35,200 40,000	490 550	2,460 2,800	2,160 2,430	4,400 5,000	2,950 3,350	6,560 7,430	1.36 1.55	4.56 5.15	5.92 6.70
Arkansas	2,180 2,340	17,220 19,400	170 190	1,210 1,360	760 820	2,150 2,420	1,380 1,550	2,910 3,240	.64 .72	2.02 2.25	2.66 2.97
California	108,800 121,500	544,000 614,000	8,700 9,620	38,100 42,000	37,800 42,400	68,000 76,800	46,800 51,620	105,800 119,200	21.60 24.00	73.50 82.50	95.10 106.50
Colorado	6,510 7,350	34,000 38,300	530 590	2,380 2,680	2,280 2,580	4,250 4,780	2,910 3,270	6,530 7,360	1.35 1.52	4.52 5.05	5.87 6.57
Connecticut	8,200 9,220	35,700 40,300	660 750	2,500 2,820	2,880 3,230	4,460 5,040	3,160 3,570	7,340 8,270	1.46 1.65	5.02 5.70	6.48 7.35
Delaware	1,600 1,850	7,020 7,910	130 150	490 550	560 650	880 960	620 700	1,440 1,610	.29 .32	1.00 1.12	1.29 1.44
District of Columbia	12,650 14,300	55,350 63,700	1,010 1,140	3,880 4,460	4,430 5,000	6,920 7,960	4,890 5,600	11,350 12,960	2.26 2.59	7.88 8.95	10.14 11.54
Florida	16,000 18,100	132,500 157,000	1,280 1,450	9,250 11,000	5,600 6,370	16,560 19,620	10,530 12,450	22,160 25,990	4.86 5.76	15.35 18.00	20.21 23.76
Georgia	11,200 12,670	58,400 65,600	900 1,010	4,060 4,600	3,920 4,440	7,300 8,200	4,960 5,610	11,220 12,640	2.30 2.54	7.78 8.78	10.08 11.32
Idaho	940 1,060	7,700 8,660	80 90	540 610	330 370	960 1,080	620 700	1,290 1,450	.29 .32	.90 1.01	1.19 1.33
Illinois	53,700 60,500	174,000 197,000	4,300 4,840	12,200 13,800	18,700 21,200	20,500 24,620	16,500 18,640	39,200 45,820	7.65 8.62	27.20 32.80	34.85 41.42
Indiana	15,250 17,200	63,900 72,200	1,220 1,380	4,480 5,050	5,360 6,060	7,990 9,020	5,700 6,430	13,350 15,080	2.64 2.97	9.30 10.50	11.94 13.47
Iowa	3,830 4,320	22,300 24,800	310 350	1,560 1,740	1,340 1,510	2,660 3,100	1,870 2,090	3,000 4,610	.87 .97	2.08 2.52	2.95 3.49
Kansas	3,640 4,110	26,000 29,300	290 330	1,820 2,050	1,280 1,440	3,250 3,660	2,110 2,380	4,530 5,100	.98 1.10	3.14 3.54	4.12 4.64
Kentucky	6,400 7,210	38,000 42,900	290 330	2,660 3,000	2,240 2,530	4,750 5,360	2,950 3,330	6,990 7,890	1.36 1.54	4.85 6.16	6.21 7.70
Louisiana	9,500 10,720	44,900 50,600	760 860	3,140 3,540	3,520 3,770	5,610 6,320	3,900 4,400	9,120 10,090	1.80 2.04	6.32 6.95	8.12 8.99
Maine	1,170 1,330	7,790 8,800	90 110	550 610	410 470	970 1,100	640 720	1,380 1,570	.30 .33	.96 1.09	1.26 1.42
Maryland	14,200 16,000	66,200 74,500	1,140 1,280	4,640 5,220	4,970 5,600	8,280 9,310	5,780 6,500	13,250 14,910	2.74 3.00	9.28 10.35	12.02 13.35
Massachusetts	38,000 42,700	70,200 78,000	3,040 3,420	4,910 5,460	13,300 14,950	8,780 9,750	7,950 8,880	22,080 24,700	3.68 4.10	15.30 17.10	18.98 21.20
Michigan	35,000 39,500	155,000 174,500	2,800 3,160	10,850 12,200	12,250 13,850	19,380 21,810	13,650 15,360	31,630 35,660	6.52 7.12	21.90 24.80	28.42 31.92
Minnesota	9,540 10,750	44,800 50,600	760 860	3,140 3,540	3,330 3,780	5,600 6,320	3,800 4,400	8,930 10,100	1.75 2.04	6.20 7.02	7.95 9.06
Mississippi	2,380 2,690	18,920 21,350	190 220	1,320 1,490	830 940	2,360 2,670	1,510 1,710	3,190 3,610	.70 .80	2.22 2.51	2.92 3.31
Missouri	15,650 17,620	80,000 90,200	1,250 1,410	5,600 6,300	5,480 6,170	10,000 11,280	6,850 7,710	15,480 17,450	3.16 3.56	10.75 12.10	13.91 15.66
Montana	1,860 2,100	8,290 9,350	150 170	580 650	650 740	1,040 1,170	730 820	1,690 1,910	.34 .38	1.17 1.32	1.51 1.70
Nebraska	3,200 3,600	13,500 15,250	260 290	940 1,060	1,120 1,260	1,690 1,910	1,200 350	2,710 3,170	.56 .63	1.88 2.20	2.44 2.83
Nevada	2,560 2,882	11,200 12,600	200 230	780 880	900 1,010	1,400 1,580	980 1,110	2,300 2,590	.45 .51	1.60 1.80	2.05 2.31
New Hampshire	780 880	5,220 6,000	60 70	360 420	270 310	650 750	420 490	920 1,060	.19 .23	.64 .74	.83 .97
New Jersey	26,500 29,200	96,700 109,000	2,120 2,340	6,750 7,630	9,280 10,220	12,090 13,620	8,870 9,970	21,370 23,840	4.11 4.62	14.80 16.50	18.91 21.12

Table H-1—Continued

	Offenses/year		Entries/month		Interrogations/month		Total		Communication time (minutes/hour)		
	Auto	Others	Auto	Others	Auto	Others	Entries	Interrogations	Entries	Interrogations	Total
New Mexico	3,040 3,390	17,500 19,700	240 270	1,220 1,380	1,060 1,190	2,190 2,460	1,460 1,650	3,250 3,650	.68 .76	2.28 2.54	2.96 3.30
New York	68,000 76,500	318,000 358,000	5,440 6,120	22,200 25,020	23,800 26,800	39,750 44,750	27,640 31,140	63,550 71,550	12.80 14.40	44.20 49.70	57.00 64.10
North Carolina	7,050 7,940	57,000 64,400	560 640	4,000 4,500	2,470 2,780	6,120 8,050	4,560 5,140	8,590 10,830	2.11 2.38	5.95 7.50	8.06 9.88
North Dakota	660 750	3,680 4,150	50 60	260 290	230 260	440 520	310 350	670 780	.14 .16	.46 .54	.60 .70
Ohio	25,900 29,200	115,800 130,500	2,070 2,340	8,100 9,100	9,050 10,220	14,480 16,310	10,170 11,440	23,530 26,530	4.66 5.15	16.30 18.40	20.96 23.55
Oklahoma	6,250 7,060	31,700 35,700	500 560	2,220 2,500	2,190 2,480	3,960 4,460	2,720 3,060	6,150 6,940	1.26 1.42	4.27 4.82	5.53 6.24
Oregon	5,120 5,770	32,600 36,600	410 460	22,280 2,560	1,790 2,020	4,080 4,580	2,690 3,020	5,870 6,600	1.25 1.40	4.07 4.58	5.32 5.98
Pennsylvania	33,400 37,600	115,000 129,800	2,670 2,990	8,050 9,030	11,700 13,180	14,380 16,220	10,720 12,020	26,080 29,400	4.95 5.55	18.10 20.40	23.05 25.95
Rhode Island	3,910 4,410	13,300 15,000	310 350	930 1,050	1,370 1,540	1,660 1,880	1,240 1,400	3,030 3,420	.57 .65	2.10 2.38	2.67 3.03
South Carolina	5,000 5,650	32,000 36,200	400 470	2,240 2,540	1,750 1,980	4,000 4,520	2,640 3,010	5,750 6,500	1.22 1.39	4.00 4.50	5.22 5.89
South Dakota	690 780	5,240 5,900	60 70	370 410	340 270	660 740	430 480	900 1,010	.20 .22	.62 .70	.82 .92
Tennessee	8,500 9,600	46,800 52,800	680 770	3,280 3,700	2,980 3,360	5,850 6,600	3,960 4,470	8,830 9,960	1.87 2.07	6.12 6.92	7.99 8.99
Texas	26,600 29,400	172,000 192,500	2,130 2,350	12,100 13,500	9,300 10,300	21,500 24,060	14,230 15,850	30,800 34,360	6.58 7.34	21.40 23.80	27.98 31.14
Utah	2,740 3,090	15,600 17,600	220 250	1,090 1,230	960 1,080	1,950 2,200	1,310 1,480	2,910 3,280	.61 .69	2.02 2.28	2.63 2.97
Vermont	520 580	2,640 2,880	40 50	170 200	180 200	330 380	210 250	510 580	.10 .11	.35 .40	.45 .51
Virginia	9,660 10,900	59,000 66,800	770 870	4,140 4,670	3,380 3,820	7,380 8,350	4,910 5,540	10,760 12,170	2.28 2.56	7.46 8.45	9.74 11.01
Washington	7,600 8,600	47,700 52,800	600 670	3,340 3,700	2,660 3,020	5,960 6,600	3,940 4,370	8,620 9,620	1.82 2.02	5.98 6.66	7.80 8.68
West Virginia	1,670 1,890	10,900 12,500	130 140	760 870	580 660	1,360 1,690	890 1,010	1,940 2,350	.41 .46	1.35 1.63	1.76 1.09
Wisconsin	8,500 9,560	32,000 37,000	680 760	2,240 2,580	2,980 3,320	4,000 4,620	2,920 3,340	6,980 7,990	1.35 1.55	4.84 5.55	6.19 7.10
Wyoming	615 695	3,920 4,420	49 56	270 310	216 244	490 550	320 380	710 790	.15 .18	.49 .55	.64 .73

[1] The upper number given in each column is the straightline extrapolation; the lower number is based on the crime rate extrapolation.

arrests for crimes of a purely local nature (arson 6,000; offenses against family, 61,000; driving while intoxicated, 242,000; drunkenness, 535,000; disorderly conduct, 510,000; and vagrancy, 120,000) leaves 2,300,000 arrests, which should be a basis for interrogation. Extrapolating this to a population of 194 million gives 3,300,000 arrests per year. This is 1.2 times as many arrests as offenses.

The 1965 interrogation rate in California for these offenses was 70 per hour, or 604,800 per year. The number of offenses in California during this time was 410,000 which represents 1.47 interrogations per offense. This is a monthly rate of 0.125 times as many interrogations as offenses per year.

$$\text{Offenses (per year)} \times 0.125 = \text{interrogations (per month)}$$

Since entries do not require a reply, it is estimated that each entry will use 20 seconds on the line, and each interrogation, with reply, will average 30 seconds on the line. Using the above methods and data from "Uniform Crime Reports," the estimates for 1970 were calculated and are given in table H-1. The figures for the United States are calculated directly from the 1965 figures, for the United States, and are not a sum total of the figures for the States.

For this analysis only the 48 continental States plus the

District of Columbia were considered. The relationship between the data of table H-1 and the parameters given previously in the cost equations is as follows:

(From table H-1)

Column 3: Entries/month, auto $= \frac{1}{2} E_{aj}$

Column 4: Entries/month, others $= E_{oj}$

Column 5: Interrogations/month, auto $= I_{aj}$

Column 6: Interrogations/month, others $= I_{oj}$

and

$$E_j = E_{aj} + E_{oj}$$

$$I_j = I_{aj} + I_{oj}$$

Inquiry line time $\tau_I = 30$ seconds average

Entry line time $\tau_E = 20$ seconds average

ESTIMATION OF REQUIRED STORAGE SIZE

The storage size requirements are based in part on data contained in the Sixth Progress Report on the NCIC project by ITSA for the FBI and in part on other data made available by the FBI.

STOLEN AUTO FILE

In estimating the storage requirements for the stolen auto file, the major parameters required are the theft or entry rate, the recovery rate or decay time of the file, and the length of time unrecovered autos will be kept in the file. From the number of auto thefts given in the UCR [2] of 486,568 and an estimated annual growth of 2.29 percent in the rate of auto thefts and 5.96 percent in population, the number of auto thefts will increase at a rate of 8.4 percent per year. It is assumed that the recovery rate of stolen autos will remain at 90 percent. Present plans for NCIC call for maintaining records of stolen autos in the file for the calendar year of theft plus 4 years. Table H-2 then gives the estimated number of stolen autos in the file at the end of each year through 1970 assuming that NCIC was fully implemented in 1966.

Table H-3 (based on data from the Los Angeles Police Department Statistical Digest) gives an assumed recovery rate as a function of time elapsed since theft as a fraction of the autos recovered (i.e., the 90 percent). It is assumed that all autos that will be recovered are recovered in 6 months. The storage factor in the table is based on the following:

Table H-2.—Unrecovered Autos in Inquiry File

Year	Number of auto thefts	Number of unrecovered autos at end of year
1965	486,568	
1966	527,330	52,733
1967	571,500	57,150
1968	619,400	61,940
1969	671,290	67,129
1970	727,550	72,755
Unrecovered autos in file at end of 1970		311,707

Table H-3.—Unrecovered Autos as a Function of Time After Theft

Time period of recovery since theft	Percent recovered per period	Cumulative percent recovered (P)	1-P	Storage factor
1st day	50.0	50.0	50.0	0.5
2d day	12.0	62.0	38.0	.38
3d day	7.0	69.0	31.0	.31
4th day	5.5	74.5	25.5	.255
5th day	4.25	78.75	21.25	.2125
6th day	3.0	81.75	18.25	.1825
7th day	2.0	83.75	16.25	.1625
8th to 31st day	12.0	95.75	4.25	2.4
32d to 181st day	4.25	100	0	3.1875
Total	100.0			7.59

1. Assume a constant number of autos stolen per day.

2. Consider only the 90 percent fraction of autos that will eventually be recovered.

3. On any day, the stolen auto file will contain 50 percent of the autos stolen the previous day, 38 percent (1–0.5–0.12) of the autos stolen 2 days previously, 31 percent (1–0.5–0.12–0.07) of the autos stolen 3 days previously, etc.

4. Therefore, on any day, the number of autos in the file is the sum of these fractions of autos not yet recovered over the previous 6 months multiplied by an assumed constant daily auto theft rate.

5. For the 8th to the 31st day and 32d to the 181st day period, a constant recovery rate is assumed. The storage factors for these two periods is given by:

$$SF_{8-31} = T_{8-31}\{U_{32} + \tfrac{1}{2}(U_8 - U_{31})\}$$

$$SF_{32-181} = T_{32-181}\{\tfrac{1}{2}(U_{32} - U_{181})\}$$

where:

SF = the storage factor for the given period.

T = number of days in the period.

U = fraction of unrecovered autos on the given day.

Then:

$$SF_{8-31} = 24\{.0425 + \tfrac{1}{2}(.1625 - .0475)\}$$
$$= 2.40$$

$$SF_{32-181} = 150\{\tfrac{1}{2}(.0425 - 0)\}$$
$$= 3.1875$$

The total number of stolen autos in the national file will then be

$$= \left[311{,}707 + .90 \times 7.59 \times \frac{727{,}547}{365}\right]$$

$$= 311{,}707 + 12{,}662 = 324{,}369$$

[2] *Crime in the United States*, Uniform Crime Reports for the United States, Federal Bureau of Investigation, Government Printing Office, Washington, D.C. 20402, 1965.

The present NCIC file format for stolen autos contains 125 characters or

$$S_{3a}=40.461 \text{ million characters}$$

required for the national stolen auto file.

For the State files, considering the sum over all the States, for Case 1 only, 1 day's records (2,000 stolen autos) are maintained or:

Case 1:

$$S_{1a}=\sum_j S_{1aj}=\frac{727{,}547}{365}\ 125=.25 \text{ million characters.}$$

For Case 2, assuming the 4-plus years of record retention, the required storage will be the same as for the national file or:

Case 2:

$$S_{2a}=\sum_j S_{2aj}=S_{3a}=40.461 \text{ million characters.}$$

Also maintained in the stolen auto file are records of stolen license plates which, however, do not show up in the UCR statistics. It is indicated in the ITSA study [3] that the number of stolen license plates is comparable to the number of stolen autos. In addition, some States keep the same license plates for 2 to 5 years. Therefore, the number of records will be bounded by (assuming equality with the number of stolen autos):

$$72{,}755+12{,}662<N<311{,}707+12{,}662$$

Since several of the more populous States do keep the same license plates for several years, a value of 160,000 records in the file was assumed. The file format for these records is 63 characters long; therefore, in the national file:

$$S_{3LP}=160{,}000\times 63=10.08 \text{ million characters.}$$

For the State files:

Case 1:

$$S_{1LP}=\sum_j S_{1LPj}=\frac{727{,}547}{365}\times 63=.126 \text{ million characters.}$$

Case 2:

$$S_{2LP}=\sum_j S_{2LPj}=S_{3LP}=10.08 \text{ million characters.}$$

WANTED PERSONS FILE

The storage requirements for the wanted persons file is based on the number of wanted person notices presently maintained in the FBI's fingerprint file extrapolated to 1970. At present, the number of notices is 80,000, and at the growth rate of 8.4 percent per year, it would be approximately 120,000 in 1970. The NCIC format contains 340 characters per record; therefore in the national file:

$$S_{3WP}=120{,}000\times 340=40.8 \text{ million characters}$$

It is estimated that the States would keep similar files on twice this number of persons or:

$$S_{2WP}=\sum_j S_{2WPj}=81.6 \text{ million characters}$$

STOLEN PROPERTY FILE

The storage requirements for the stolen identifiable property is based on the ITSA [4] report. Records will be kept in the file for the year of theft plus 2 years. It is estimated that 20 percent of the property is recovered in the year of theft and 10 percent in each of the succeeding years. The results are summarized in table H–4 where the number of records at end of the year is given by:

$$=147{,}500\times .8+133{,}750\times .7+121{,}250\times .6$$

The file format for these records contains 100 characters; therefore, the size of the national file is:

$$S_{3SP}=28.44 \text{ million characters}$$

It is estimated that the State files will contain twice as many records or:

$$S_{2SP}=\sum_j S_{2SPj}=56.88 \text{ million characters}$$

STOLEN GUN FILE

The final file considered in this analysis is the stolen gun file. In the ITSA [5] report, a rough estimate is made that this file, by the end of 1970, would contain approximately 100,000 records. The file format for this record contains 78 characters or:

$$S_{3SG}=7.8 \text{ million characters}$$

Table H–4.—Unrecovered Property in Inquiry File

Year	Estimated entries	Number of records at end of year
1967	110,000	
1968	121,250	
1969	133,750	257,875
1970	147,500	284,375

[3] Letter report from Donald R. Macken, Institute for Telecommunication Sciences & Aeronomy, to J. J. Daunt, FBI; Subject: Sixth Progress Report in a series on the National Crime Information Center Telecommunications Study, ITSA Project No. V52362420; Nov. 1, 1966.

[4] *Ibid.*

[5] *Ibid.*

Table H–5.—Storage Requirements for the Inquiry Files

File	Record size (characters)	National: Number of records	National: Number of characters (millions) S_3	Total, all States (case 1): Number of records	Total, all States (case 1): Number of characters (millions) S_1	Total, all States (case 2): Number of records	Total, all States (case 2): Number of characters (millions) S_2
Stolen auto	125	324,369	40.46	2,000	0.25	324,369	40.46
Stolen license plates	63	160,000	10.08	2,000	.126	160,000	10.08
Wanted persons	340	120,000	40.80	240,000	81.60	240,000	81.60
Stolen property	100	284,375	28.44	568,750	56.88	568,750	56.88
Stolen guns	78	100,000	7.80				
Total			127.58		138.86		189.02

Additionally, in the analysis it is assumed that the States do not maintain a duplicate file, so

$$S_{1,2SG}=0$$

Table H–5 summarizes the storage requirements developed.

COST FACTORS

As mentioned previously, the analysis is based on three major cost factors, the cost of computation, the cost of computer storage, and the cost of communication. The most difficult to estimate is the cost of computation, especially when it is considered that there may be as many as 50 different systems implemented (the 48 continental States, the District of Columbia, and the national system). Because of these difficulties, an incremental cost model with identical linear costs was assumed. An incremental cost model, however, is not the best model for a fragmented system since it does not consider:

- ☐ Variations in the ratio of fixed to variable costs due to different size facilities required in the different States;
- ☐ Variation in the cost per computation as function of speed of computation (the square law of computers indicates that Cost $\approx \sqrt{\text{Speed}}$).

The cost of computation, based on budgetary estimates for NCIC, considering a duplex 360/40 system, including cost of personnel, is assumed at \$36,000 per month or \$50/hr (720 hr month). As mentioned before, it is assumed that the time required to process one entry or one inquiry is one second. A factor of 4 is used to take into account queueing delays, other computer processing (program checkout, etc.), and idle time resulting from the variation of demand over the 24 hr day, giving an average processing rate of 900/hr. This gives a cost per entry or inquiry of:

$$C_c=\frac{\$50}{900}=\$.056/\text{entry or inquiry}$$

The computer storage cost is based on the cost of a Disk Pack memory (IBM 2314) quoted in a General Services Administration price list.

$$C_s=\frac{\$5250/\text{month}}{207 \text{ million char.}}\cong\$25/\text{month/million characters}$$

The communications cost estimate is based on the General Services Administration communication cost used in purchasing A.T. & T. Telpak services for Government agencies. These are based primarily on Telpak C and Telpak D tariff structures. The GSA charges are on a mileage basis plus a monthly terminal charge. The charges used in this analysis are \$262.50 per month for terminal and line conditioning plus 45¢ per mile per month. This is based on a single 4 kHz voice grade line which can be subdivided into six 100 word per minute duplex teletype circuits. On a per duplex circuit basis:

$$C_t=\$43.75/\text{month}$$
$$C_l=\$.0825/\text{mile/month}$$

This includes a 10 percent wasted capacity cost because of inefficiencies in grouping the narrow band lines from the single terminal location at each State capitol.

COST SUMMARIES

The following summarizes the various cost elements developed previously:

$$C_1=C_c\sum_j(E_j+I_j)$$

$$=\$0.056\ (355{,}912+685{,}746)=\$58{,}332.85$$

$$C_{21}=C_s\sum_j S_{1j}$$

$$=\$25\ (138.86)=\$3{,}471.50$$

$$C_{22}=C_s\sum_j S_{2j}$$

$$=\$25\ (189.02)=\$4{,}725.50$$

$$C_{31}=C_c\sum_j(E_{oj}+\tfrac{1}{2}E_{aj}+I_j)$$

$$=\$0.056\ (240{,}160+57{,}876+685{,}764)=\$55{,}092.80$$

$$C_{32}=C_c\sum_j(E_{oj}+\tfrac{1}{2}E_{aj}+I_{oj}+.05\ I_{aj})$$

$$=\$0.056\ (240{,}160+57{,}876+431{,}000$$

$$+.05\ (254{,}764))=\$41{,}539.36$$

$$C_4 = C_s S_3$$

$$= \$25 \times (127.58) = \$3,189.50$$

$$C_5 = C_c \sum_j (E_{oj} + \tfrac{1}{2} E_{aj})$$

$$= \$0.056\ (240,160 + 57,876) = \$16,690.02$$

$$C_6 = C_c \{ \sum_j (E_j + I_j) + \sum_j (\sum_k (I_{ok} + .05 I_{ak}) - (I_{oj} + .05\ I_{aj})) \}$$

$$= \$0.056 \{ (355,912 + 685,746) + 48(431,000 + .05\ (254,764) \}$$

$$= \$1,251,101.13$$

The cost of communication is the only cost which is a function of the choice of location(s) of the national file. Because of the particular form of the equations and the need to minimize the sum, these costs had to be computed by means of a computer program. The results are summarized below:

$$C_7 = \min \sum_j (C_t + C_l d_j) L_{1j}$$

$$= \min \sum_j (\$43.75 + \$.0825\ dj) L_{1j}$$

$$= \$7,909.60 \text{ (Location: Springfield, Ill.)}$$

$$C_8 = \min \sum_j (C_t + C_l dj) L_{2j}$$

$$= \$6,909.14 \text{ (Location: Springfield, Ill.)}$$

$$C_9 = \min \Big[\{ \sum_k (C_t + C_l d_k) L_{1k} \} + \{ \sum_l (C_t + C_l d_l) L_{1l} \} + (C_t + C_l d_{kl}) L_3 \Big]$$

$$= \$7,071.38 \text{ (Locations: Harrisburg, Pa.-Denver, Colo.)}$$

$$C_{10} = \min \Big[\{ \sum_k (C_t + C_l d_k) L_{2k} \} + \{ \sum_l (C_t + C_l d_l) L_{2l} \} + (C_t + C_l d_{kl}) L_3 \} \Big]$$

$$= \$6,257.12 \text{ (Locations: Harrisburg, Pa.-Denver, Colo.)}$$

$$C_{11} = \min \sum_j (C_t + C_l d_j) L_{4j}$$

$$= \$112,420 \text{ (Location of switching center: Springfield, Ill.)}$$

These costs are summarized for various locations in tables H–6, H–7, and H–8. The total systems costs for the various alternatives are summarized in table H–9.

The lowest national and total system cost occurred for a centralized system located at Springfield, Ill. (Case 2). However, there would be an increase of only $840 per month if the location were moved to Washington, D.C. Since other costs such as facilities, staffing, and administrative control would far outweigh this, these computations would indicate that any other city, including Washington, D.C., would be as good a choice for the location of the national system. These computations do show that, within the assumptions, it would be best if the States maintained their own stolen auto file. This does not mean necessarily that the national system could not provide this service for some interim period or, in the case of smaller States, for an indefinite period.

Table H–6.—Communication Costs for Centralized Inquiry Systems

Centralized system	Total number of line miles	Communications costs (C_7)	Centralized system	Total number of line miles	Communications costs (C_8)
Case 1 (L_1=72)			Case 2 (L_2=63)		
Springfield, Ill	57,692.1	$7,909.60	Springfield, Ill	50,338.1	6,909.14
Indianapolis, Ind	58,235.4	7,954.42	Indianapolis, Ind	50,670.7	6,936.58
Jefferson City, Mo	59,222.4	8,035.85	Jefferson City, Mo	51,639.9	7,016.54
Madison, Wis	60,232.9	8,119.21	Madison, Wis	52,499.2	7,087.43
Washington, D.C	69,471.6	8,881.41	Washington, D.C	60,512.1	7,748.50

Table H–7.—Communication Costs for Two Locations for Centralized Inquiry Systems

Two-Location centralized system	Total number of line miles	Communications cost	Number of interconnecting lines ($L3$)	Number of interconnecting line miles	Interconnecting communications cost	Total communications cost
Case 1 (L_1=72)						(C_9)
Harrisburg, Pa.-Denver, Colo	37,476.5	$6,241.81	5	7,403.82	$829.57	$7,071.38
Columbus, Ohio-Sacramento, Calif	34,101.8	5,963.40	6	12,258.1	1,273.79	7,237.19
Indianapolis, Ind.-Denver, Colo	39,693.3	6,424.69	6	5,988.32	756.54	7,181.23
Washington, D.C.-Sacramento, Calif	37,300.0	6,227.27	6	14,217.7	1,436.46	7,662.73
Washington, D.C.-Denver Colo	37,869.5	6,274.23	5	7,442.87	832.79	7,107.02
Case 2 (L_2=63)						(C_{10})
Harrisburg, Pa.-Denver, Colo	32,379.4	5,427.55	5	7,403.82	829.57	6,257.12
Columbus, Ohio-Sacramento, Calif	30,320.6	5,257.70	6	12,258.1	1,273.79	6,531.49
Indianapolis, Ind.-Denver, Colo	34,272.8	5,583.75	6	5,988.32	756.54	6,340.29
Washington, D.C.-Sacramento, Calif	33,080.0	5,485.35	6	14,217.7	1,435.46	6,920.81
Washington, D.C.-Denver, Colo	32,550.0	5,441.62	5	7,442.87	832.79	6,274.41

Table H–8.—Communications Costs for Decentralized Inquiry Systems

Location of switching center (L_4=1073)	Total number of line miles	Communications cost (C_{11})
Springfield, Ill	793,652	$112,420
Indianapolis, Ind	797,369	112,[illegible]27
Jefferson City, Mo	814,565	114,145
Madison, Wis	833,294	115,690
Washington, D.C	961,598	126,275

For the two-location system, the major difference in cost was the cost attributed to each of the two information centers updating each other. If this cost were removed by assuming that such updating was accomplished during times of low demand (in effect reducing the size of the computer required for meeting the peak demand), the centralized system is slightly less expensive, since the savings in communications by having two or more centers would be more than offset by the increase in storage costs. The additional administrative costs of the two locations, which have not been taken into account, would far outweigh any difference calculated here. From the point of view of system reliability, although two locations might have some small advantages, a single location can be made more than sufficiently reliable for this application.

The decentralized system suffers from the major problem that all States must process the inquiries of all other States and the resulting communications and administrative costs are high. Admittedly, this is an extreme case, but it illustrates the problem of trying to provide a national capability without a centralized national system. On the other hand, if the States were interested in maintaining only information of concern to themselves without any national exchange, the costs would be essentially that given as the State costs for a Case 2 situation, i.e., about $63,000 per month.

This cost model is admittedly crude and does not take into account such items as the ratio of fixed to variable costs, the relatively high cost per operation for small computers, and data conversion costs. It is indicative, however, of the magnitude of the costs and the relative costs of the several system alternatives investigated.

Table H–9.—Total Costs for Inquiry Systems

	National costs per month				All States, costs per month			Total
	Communication system	Computer operating	Computer storage	Total	Computer operating	Computer storage [1]	Total	National and States, costs per month
Centralized system (location,[2] Springfield, Ill.):								
Case 1	$7,909.60	$55,092.80	$3,189.50	$66,191.90	$58,333.86	$3,471.50	$61,805.36	$127,997.26
Case 2	6,909.14	41,539.36	3,189.50	51,638.00	58,333.86	4,725.50	63,059.36	114,697.36
Centralized system (location, Washington, D.C.):								
Case 1	8,881.41	55,092.80	3,189.50	67,163.71	58,333.86	3,471.50	61,805.36	128,969.07
Case 2	7,748.50	41,539.36	3,189.50	52,477.36	58,333.86	4,725.50	63,059.36	115,536.72
Two location system (locations,[2] Harrisburg, Pa. and Denver, Colo.):								
Case 1	7,071.38	71,782.82	6,379.00	85,233.20	58,333.86	3,471.50	61,805.36	147,038.56
Case 2	6,257.12	58,229.38	6,379.00	70,865.50	58,333.86	4,725.50	63,059.36	133,924.86
Two location system (locations, Denver, Colo. and Washington, D.C.):								
Case 1	7,107.02	71,782.82	6,379.00	85,268.84	58,333.86	3,471.50	61,805.36	147,074.20
Case 2	6,274.41	58,229.38	6,379.00	70,882.79	58,333.86	4,725.50	63,059.36	133,942.15
Decentralized system:								
Case 2	126,276.00			126,276.00	1,251,101.13	4,725.50	1,255,826.63	1,382,102.63

[1] Includes estimates of stolen property and wanted persons files not maintained on national level.
[2] Minimum cost locations.

Notes: Estimates are for 1970.
Functions included are stolen auto and license plates, stolen identifiable property, guns, and wanted persons.
Case 1: States do not maintain stolen auto file beyond 24 hours.
Case 2: States do maintain stolen auto file beyond 24 hours.

DATA ANALYSES AND SIMULATION OF COURT SYSTEM IN THE DISTRICT OF COLUMBIA FOR THE PROCESSING OF FELONY DEFENDANTS

by Joseph A. Navarro and Jean G. Taylor

Contents

In chapter 4, the Task Force study of the processing of felony defendants in the District Court for the District of Columbia is summarized. This appendix provides more detailed description of the court statistics and the simulation model. To provide continuity in the appendix, certain parts of the summary in chapter 4 have been repeated here.

INTRODUCTION

For years judges, lawyers, and court administrators have been grappling with the problem of delay. Many solutions have been tried but found wanting. Some have been rejected out of hand; others, obvious to a management expert, either have not been thought of or have been deemed too disrupting for the anticipated improvement. A test of any proposed solution might require considerable disruption of court operations and a vast expenditure of time and energy which might prove worthless. Courts could be helped appreciably if means were developed for accurately analyzing the causes of delay and then pretesting alternative approaches to reducing delay.

The Task Force has explored the feasibility of computer simulation of court operations to meet this need. Briefly, a simulation model is a representation of the system and its operations which can be used to examine the effect of changes in the system.[1] In the courts, simulation could provide a means for examining methods for expediting the processing of defendants through the system. Further, simulated pretesting provides a first estimate of the effects of proposed changes on resources, workloads, and delays. This process allows the administrator to test alternative allocations of resources and find the combination which balances delay reduction against expended resources.

The simulation developed here required, as all simulations do, first, a description of the system being simulated; and, second, collection and analysis of data describing court operations. Only then could the model be constructed and manipulated. Thus the work was conducted in three parts:

1. The organization and structure of the trial court system for the District of Columbia[2] and its procedures for processing felony defendants were described.
2. The available data on felony defendants in the District Court were analyzed to determine the distribution of total time to disposition, time intervals between major events in the system, potential areas of delays, and possible causes.
3. A simulation model of the processing of felony defendants in the District of Columbia trial court system was developed which:
   a. Operated like that observed in the data (i.e, to produce the average time intervals between steps in the process similar to those observed in the data).
   b. Could be manipulated to investigate possible organizational or procedural changes in the system and to measure their impact on reducing delay and on the available resources in the system.

In this analysis neither the substantive law nor the use of improved business practices were addressed.

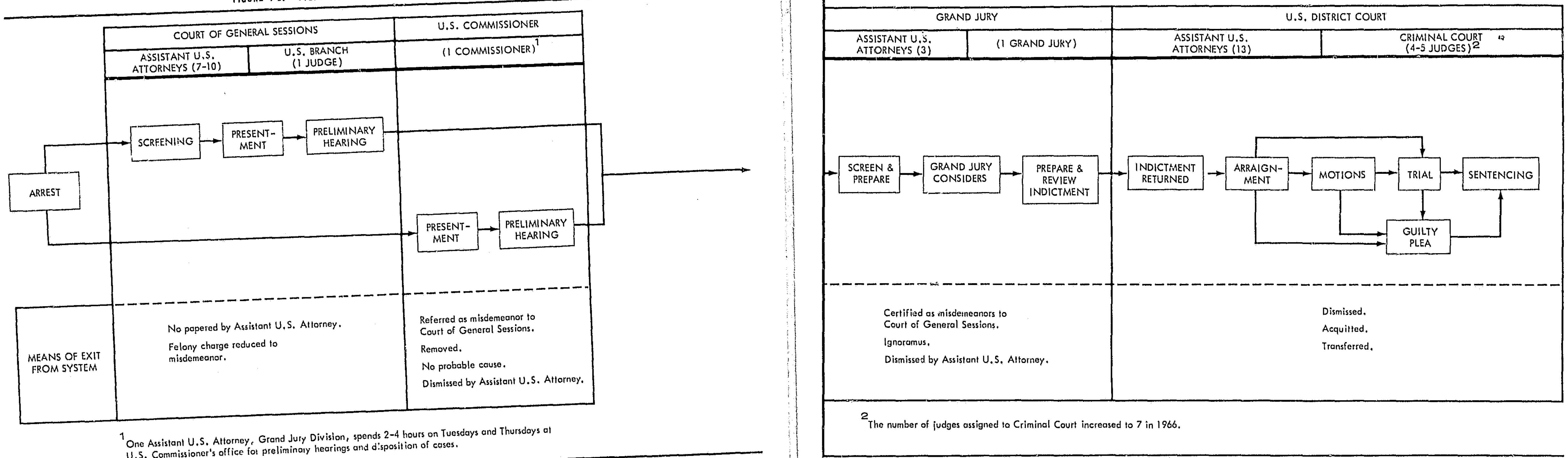
THE D.C. COURT SYSTEM FOR PROCESSING FELONIES

The U.S. District Court for the District of Columbia (referred to hereafter as the District Court) is unique in the Federal system because it has jurisdiction over all felonies committed in the District of Columbia. It

[1] Simulation has been used successfully by the military and industry for planning and for evaluating various courses of action.

[2] Because of the many differences among the court systems in the United States, the task force examined only 1 court in detail, the U.S. District Court of the District of Columbia. The methodology, however, is applicable to any jurisdiction which can collect adequate data about its present operations.
Hereafter, the term "District Court" is used for convenience; it should be understood that this refers only to the U.S. District Court for the District of Columbia and not the other Federal district courts.

FIGURE I-1. STEPS IN PROCESSING OF FELONY DEFENDANTS



is not confined, like other Federal courts, to Federal crimes such as tax evasion and fraud. It also processes felonies which would ordinarily be handled in a State court. Further, because the court is operating in a Federal jurisdiction, the procedure followed in all criminal cases is that of the Federal Rules of Criminal Procedure and the interpretation of these rules by the court.[3] Similarly, Federal legislation such as the Bail Reform Act[4] and the Criminal Justice Act[5] apply to all cases.

The first step in the development of a simulation is a description of the court system. This must be described in terms of the flow of defendants and the flow of information through the system, and the assignment of the court resources (judges, courtrooms, attorneys, etc.) to the various events associated with the processing of the defendants.

The various steps and the associated resources for processing felony defendants in the District of Columbia court system[6] are shown in simplified form in figure I–1. The first step is presentment,[7] which occurs before a judge of the Court of General Sessions (the municipal court of the District of Columbia),[8] or the U.S. Commissioner. Both are available for presentment and preliminary hearing in felony cases. Presentment is often preceded by a review or screening of the case by an Assistant U.S. Attorney (Court of General Sessions Division). He determines whether to reduce the felony charge to a misdemeanor, to terminate the case ("no papering"), or to proceed with prosecution.

In 1965, the U.S. Branch[9] of the Court of General Sessions handled approximately 12,000 defendants. About 5,200 of these were arrested on a felony charge. In addition, the U.S. Commissioner received about 1,100 felony defendants. From among these 6,300 persons arrested for a felony charge, about 2,000 were held for action by the grand jury (i.e., the defendant had either waived preliminary hearing or the preliminary hearing had led to a finding of probable cause to hold the accused for grand jury action).[10]

A case is next processed in the office of the U.S. Attorney (Grand Jury Unit). It is screened again and calendared for presentation to the grand jury.[11] The grand jury votes an indictment if there is concurrence

[3] For example, *Mallory* v. *United States*, 354 U.S. 449 (1957).
[4] Bail Reform Act of 1966, P.L. 89-465, 18 U.S.C. 3146-3152.
[5] Criminal Justice Act of 1964, 78 Stat. 522, 18 U.S.C.A. 3006A.
[6] Only that part of the District of Columbia court system pertaining to the processing of felony cases is included; those parts that deal exclusively with misdemeanors are not examined.
[7] This is the first judicial appearance and has been variously called presentment, initial presentment, initial appearance, or preliminary arraignment. Under Rule 5, Federal Rules of Criminal Procedure, this appearance must be "without unnecessary delay", interpreted to mean much less than 24 hours (*Mallory* v. *United States*, 354 U.S. 449 (1957)).
[8] The structure and operation of the U.S. Branch of the Court of General Sessions have been described in detail by: Harry I. Subin, "Criminal Justice in a Metropolitan Court: The Processing of Serious Criminal Cases in the District of Columbia Court of General Sessions," Office of Criminal Justice. U.S. Department of Justice, Washington, D.C., October 1966.
[9] Other branches of the Court of General Sessions process violations of municipal ordinances and other petty offenses prosecuted by the Corporation Counsel for the District of Columbia.
[10] Figures are based on data from fiscal year 1965, and so do not reflect precisely the current situation.
[11] "An offense which may be punished by death shall be prosecuted by indictment. An offense which may be punished by imprisonment for a term exceeding 1 year or at hard labor shall be prosecuted by indictment, or if indictment is waived, it may be prosecuted by information. Any other offense may be prosecuted by indictment or by information. An information may be filed without leave of court." (Fed. Rules of Crim. Proc., Rule 7(a).) Available District of Columbia data indicates that only 5–10 percent of the felony defendants waive grand jury indictment.

of 12 or more of the jurors.[12] Thereafter, the indictment is signed by the foreman and by the U.S. Attorney and returned (generally on Monday) in open court.

Arraignment is the next step. It is in general a perfunctory proceeding in which the accused appears,[13] is advised of the formal charge and enters a plea—usually not guilty. At about this time the case is assigned to an Assistant U.S. Attorney who will probably handle it until final disposition, and a defense counsel is appointed by the court for a defendant who cannot afford counsel.

Following arraignment, trial preparation proceeds, motions are filed and heard, the case is placed on a calendar[14] and finally progresses to trial. Of the defendants disposed of in 1965, only about 30 percent completed the final step of trial; approximately 55 percent pleaded guilty to the offense charged or to a lesser offense prior to or during the trial. The remaining 15 percent of the defendants were dismissed.

ELAPSED TIME FOR PROCESSING OF FELONY DEFENDANTS IN THE DISTRICT OF COLUMBIA COURT SYSTEM

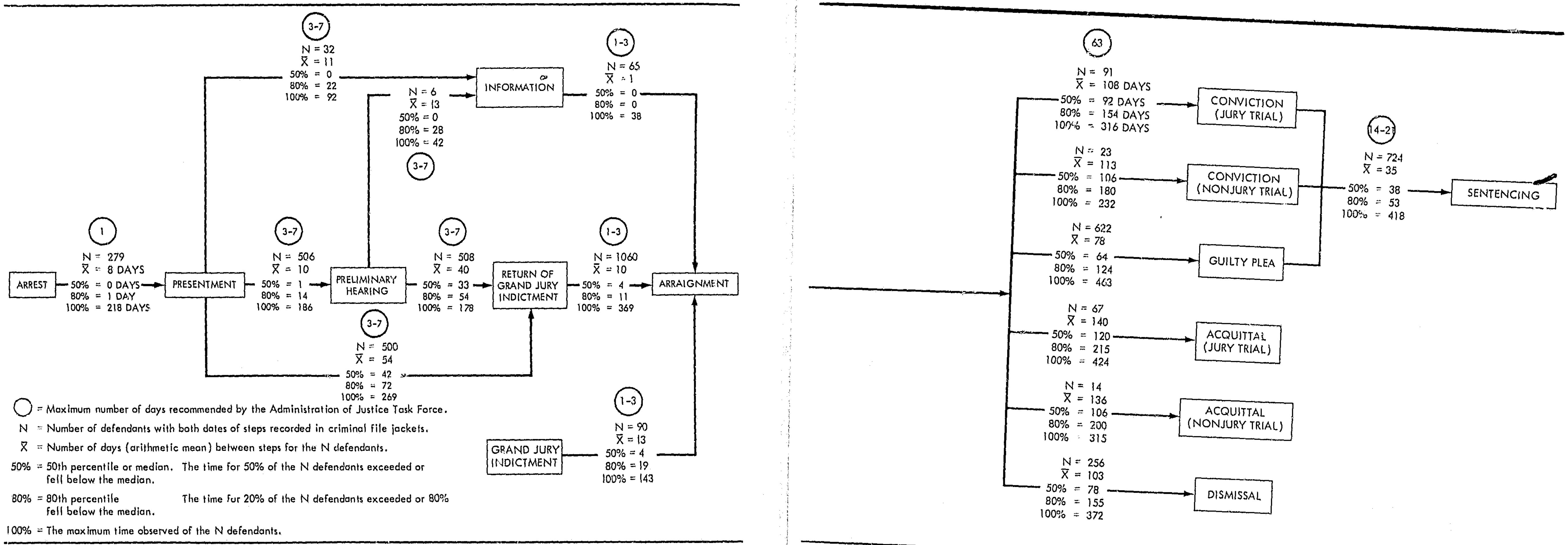
Data collected for the D.C. Crime Commission were analyzed to estimate the elapsed time in processing defendants through the District Court.[15] While these data were probably the most comprehensive ever collected in a criminal court system they still had some limitations.

First, the data were collected from the criminal jackets (or records) of the felony cases which were commenced in the District Court in calendar years 1950, 1955, 1960, and 1965.[16] Felony cases which, one way or another, were reduced to misdemeanors and prosecuted in the Court of General Sessions are thus excluded.

Second, the data measure the days, weeks or months *between* various stages of the criminal process. The detailed data on the hours and minutes required to perform each step of the process were not available.

[12] The indictment is prepared by a clerk in the U.S. Attorney's office, proofread by each of the three Assistant U.S. Attorneys, and reviewed by both the Chief Assistant of the Grand Jury Unit and the Chief Assistant of the Criminal Trial Division.
[13] Defendants in the District of Columbia are not usually notified by the court of their indictment. If the defendant is in jail, the jailor is notified to produce the defendant on the day of arraignment. If the defendant is on money bond, his bondsman is notified to produce the defendant. Otherwise, the defendant must read it in the newspaper and appear. If he does not appear, a bench warrant is issued for his arrest
[14] Calendar systems vary with jurisdiction. The system presently used in the District Court places all cases on a master calendar as soon as the indictment is returned; when motions are completed or the time to file motions has expired, the case is placed on the reserve calendar; and, finally, when all impediments are removed (e.g., defendant's mental exam completed, all witnesses are available, lab analyses completed), the case is placed on the ready calendar. Cases may then be scheduled for trial according to various priorities. Cases where defendants are in jail are scheduled ahead of those on bail; these, in turn, are scheduled in order of date of indictment providing there is no conflict of prosecuting attorneys. This system was implemented in late 1966.
[15] These data are more fully analyzed in a report "Court Operations: Data Analyses and Simulation of the Processing of Felony Defendants in the Trial Court System of the District of Columbia" in preparation. The report will be available from the Clearinghouse of Federal Scientific and Technical Information of the National Bureau of Standards.
[16] 1965 data is partially incomplete because all cases commenced in 1965 were not complete by the time of the data collection in May 1966. Average times for 1965 are therefore somewhat understated because some of the very long times are not in the sample.

FIGURE I-2. DAYS BETWEEN ARREST AND ARRAIGNMENT STEPS IN PROCESSING OF FELONY DEFENDANTS - 1965



Finally, it should be noted that the District Court handles a very small proportion of criminal cases. In the District of Columbia there were approximately 150,000 nontraffic adult arrests in fiscal year 1965, but only about 6,300 adult persons were arrested on felony charges. Only 1,603 of those came before the District Court; the other 4,700 either had their cases reduced to a misdemeanor charge, no papered, or otherwise dropped.[17]

The median time for trial court disposition of cases commenced in 1965 was 5.5 months. For nontrial disposition, the median was 4.5 months.[18] The observed times between the various stages of the process are shown on figure I-2. The median intervals are summarized in table I-1.

The observed time between processing stages can be compared to the model timetable [19] proposed by the Administration of Justice Task Force. That Task Force concluded that the processing of criminal cases takes too long and recommended a model timetable (table I-2) with a maximum of 4 months from arrest to trial court disposition. Figure I-2 shows that the observed times in the collected data are appreciably longer than those in the recommended timetable.

In order to compare the processing times in the collected data with the model timetable and find causes of delay, a more detailed analysis of the data is needed. For example, do time intervals at each step in the process vary substantially when different statistical measures of time (e.g., mean, median, or 80th percentile) are used? Are there substantial variations in processing times for persons indicted as distinguished from persons against whom informations were filed? Do these vary depending on whether the case is presented in the Court of General Sessions as distinguished from presentment to the U.S. Commissioner?

The numerical value of the time interval between stages was found to depend significantly on whether mean or median time statistics were used. The mean exceeded the median at every step of the process between arrest and trial or nontrial disposition (fig. I-2). This difference indicates that the distributions of times are skewed positively, that is, there are some very high values, i.e., while most cases are dealt with in a relatively narrow range of time, a few cases take very much longer time to process. Furthermore, when the median values are compared with the model timetable, it is found that about 50 percent of the defendants are being processed in accordance with the model timetable at all prearraignment stages of the process except for the stage between preliminary hearing (or presentment if preliminary hearing is waived) and indictment.[20] However, if one looks at the amount of time required to process the 80th percentile defendant, all steps of the process are 2 to 4 times longer than the maximum of the model timetable.[21]

The time interval between arrest and indictment was found to depend strongly on where presentment occurred. The processing time for cases presented to the U.S. Commissioner was usually longer than processing time for cases initiated in the Court of General Sessions (table I-3). If there is no preliminary hearing, the median time between presentment in the Court of General Sessions and indictment is 39 days, and 58 days when the U.S. Commissioner handles the case. If there is a preliminary hearing, time between the hearing and indictment among cases initiated in either the Court of General Sessions or the U.S. Commissioner is 34 days; however, the median interval be-

[17] The data analyses that follow are based on 1,550 of the 1,603 defendants. Fifty-three defendants were not included due to errors in transposing the data from the criminal jacket to the data base.

[18] The data for 1950, 1955, and 1960 were analyzed in the same way as the 1965 data but not presented here because the court structure and operation during those periods are known in less detail and hence the data interpretation is less meaningful. These data are available from the Institute for Defense Analyses.

[19] The model timetable for felony cases is discussed on pp. 154–155 of the Commission's report.

[20] The greatest proportion of prearraignment time is spent awaiting return of indictment. The 40 days which elapse between presentment and indictment are substantially in excess of the recommended maximum time of 3–7 days.

[21] Because some of the times between arrest and arraignment seemed unduly long, they were checked against the 1966 situation and no significant difference was found. In fact, with the promulgation of local criminal rule 87 some times have actually increased. Specifically, in 1966, 2 weeks elapse between the time when a defendant is held for action by the grand jury and the time when his case is presented to the grand jury; another 2 weeks usually elapse before the indictment is returned in open court although on occasions it only requires 6 days; thereafter the rule allows 8–12 days between indictment and arraignment rather than the 4 days observed in 1965 data.

Table I-1.—Median Elapsed Times Between Stages in the District of Columbia Courts for Defendants Whose Cases were Filed in the District Court in 1965

Step in process	Number defendants [1]	Time interval, median (in days)
Arrest to presentment	279	<1
Presentment to preliminary hearing	506	1
Preliminary hearing to indictment	508	33
Presentment to indictment (preliminary hearing waived)	500	42
Indictment to arraignment	1,060	4
Arraignment to conviction (jury trial)	91	92
Arraignment to conviction (court trial)	23	106
Arraignment to guilty plea	622	64
Arraignment to dismissal	256	78
Arraignment to acquittal (jury trial)	67	120
Arraignment to acquittal (court trial)	14	106
Conviction to sentencing	724	38

[1] The number of defendants upon which the observed medians are based is less than the total of 1,603 defendants whose cases were commenced in the District Court; the data were incomplete or inaccurate in many cases, and not all defendants were processed through the same stages of the system.

Table I-2.—Model Timetable

Step in process	Maximum time interval (days)	
	Jail cases	Bail cases
Arrest to presentment	<1	<1
Presentment to preliminary hearing	3	7
Preliminary hearing to formal charge [1]	3	7
Presentment to formal charge (if preliminary hearing is waived)	3	7
Formal charge to arraignment	1	3
Arraignment to trial	63	63
Trial to sentencing	14–21	

[1] Formal charge can be by either indictment of information.

tween presentment and preliminary hearing is 9 days longer for cases before the Commissioner.

Possible causes of the differences emerge from an examination of the practices of the Court of General Sessions and the U.S. Commissioner. The data in table I–3 indicate that the Court of General Sessions processed more defendants than the Commissioner, but there was a substantial difference in the types of crimes. Eighty percent of the defendants processed at the Court of General Sessions were charged with either robbery, assault, burglary, larceny, auto theft, or rape. On the other hand, 70 percent of the defendants who were processed by the U.S. Commissioner were charged with murder, narcotics, gambling, robbery, or forgery. In addition, it was observed that the U.S. Commissioner holds hearings on Tuesday and Thursday mornings and generally schedules preliminary hearings for 2 weeks after initial presentment. In contrast the Court of General Sessions does not continue preliminary hearings for 2 weeks and, in fact, holds half of the preliminary hearings on the day of initial presentment.

Detailed data analysis can be used to rule out possible causes of delay. For example, a preliminary hearing does not materially increase the amount of time between arrest and indictment. On the other hand, this time can be sensitive to the type of crime. An example of such a comparison is plotted on figure I–3. Aside from gambling, which took by far the longest, most types of crimes had comparable time distributions. This phenomenon may be explained by a local practice in which the demand for a preliminary hearing is really a device for obtaining a continuance in the early stages of the process. Thus every defendant demands a preliminary hearing, but many ultimately waive it when the scheduled day arrives.

The data suggested that motion practice contributes to delay. In 1965 approximately half of the defendants filed one or more motions prior to disposition. Table I–4 shows that in those cases where no motions were filed, the median time from arraignment to nontrial disposition (guilty plea or dismissal) was 7 weeks; to trial disposition, it was 11 weeks. Where two or more motions were filed, these median times were doubled. A median of 40 days elapsed between arraignment and the filing of the first motion, and 30 days between the filing of the first and second motions. This clearly establishes the need for enforcement of the new 10-day motion rule.[22]

The distribution of time between various stages and formal disposition is shown in figure I–4. The median time from arraignment to nontrial disposition (by guilty pleas and dismissals) is between 2 and 3 months. The median time from arraignment to trial disposition (either jury or nonjury) is 3 to 4 months. When the time in the system prior to arraignment is added, the median time for nontrial disposition is 4.5 months and for trial disposition is 5.5 months. For the convicted, an additional median time of 38 days elapse between conviction and sentencing. The time between arraignment and disposition varies with the type of felony. Gambling, murder, and assault take the longest; burglary, auto theft, and robbery take the shortest time. The time also varies with the types and number of motions filed [23] and the tactics of counsel; but the effects of the latter are not easily measured except when they request continuances or file motions.

The median processing times from presentment to disposition as shown in figure I–4 exceed the maximum of

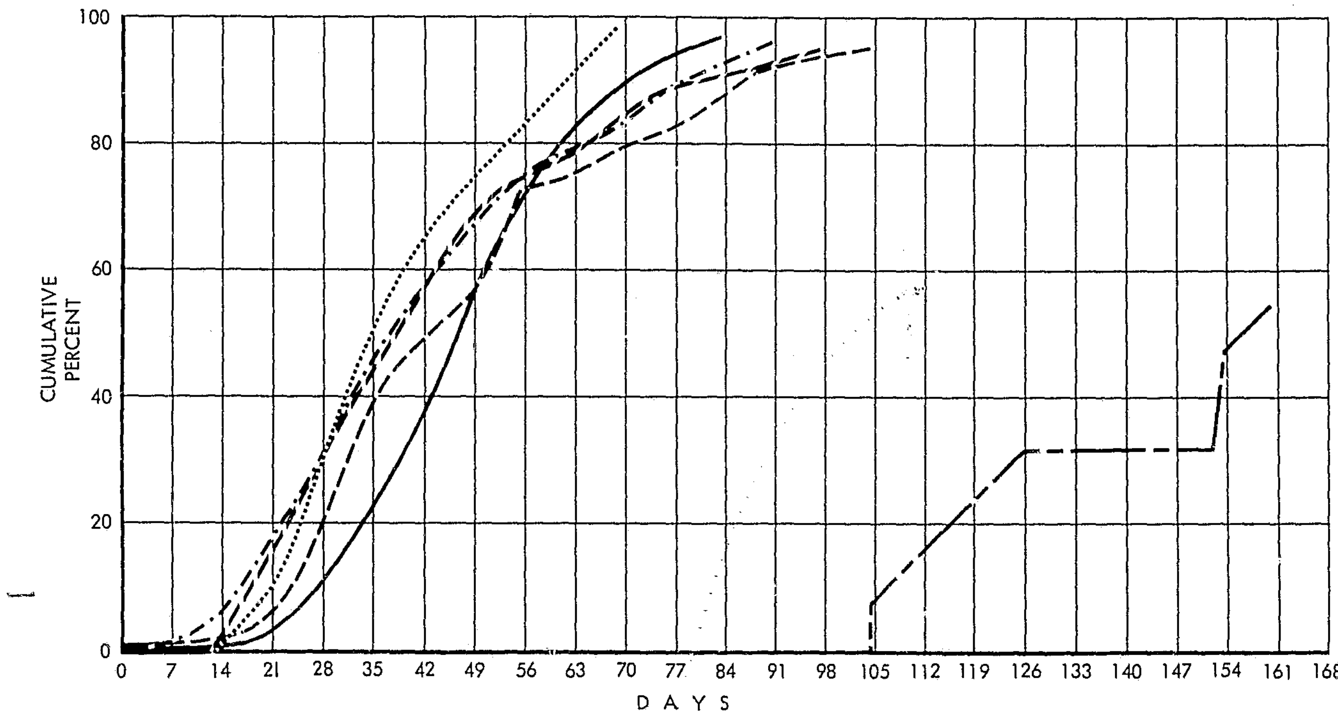
Table I–3.—Comparison of Time Intervals (in days) for Preliminary Processing of Felony Defendants whose Cases were Filed in the District Court in 1965

Time interval	U.S. Branch, Court of General Sessions					U.S. Commissioner				
	No. of defendants	Mean	Percentiles			No. of defendants	Mean	Percentiles		
			50	80	100			50	80	100
Presentment to preliminary hearing	255	6	0	8	186	193	18	9	24	150
Preliminary hearing to return of indictment [1]	252	39	34	53	105	187	41	34	53	178
Presentment to return of indictment (preliminary hearing waived)	327	47	39	65	240	118	83	58	146	271
Presentment to information (preliminary hearing waived)	3	(not meaningful statistics) [2]				3	(not meaningful statistics) [3]			

[1] In general these are the same defendants considered in previous row.
[2] The three times were 8, 23, and 38 days.
[3] The three times were 38, 53, 63 days.

[22] An amended Rule 87 of the Criminal Rules of the District Court for the District of Columbia became effective October 1966. This rule requires that all motions be filed within 10 days after arraignment and be heard the second Friday following the filing date. Exceptions to the rule are considered by the Chief Judge.

FIGURE I-3. TIME BETWEEN PRESENTMENT AND RETURN OF INDICTMENT WHEN PRELIMINARY HEARING HELD - 1965



MOST SERIOUS CRIME CHARGE	NUMBER OF DEFENDANTS	DAYS BETWEEN PRESENTMENT AND RETURN OF INDICTMENT		
		MEAN	MEDIAN	MAXIMUM
MURDER 1° & 2°	45	50	46	115
ROBBERY	126	44	39	105
ASSAULT	74	51	46	168
BURGLARY	71	47	39	136
AUTO THEFT	49	40	39	87
GAMBLING	13	164	157	290

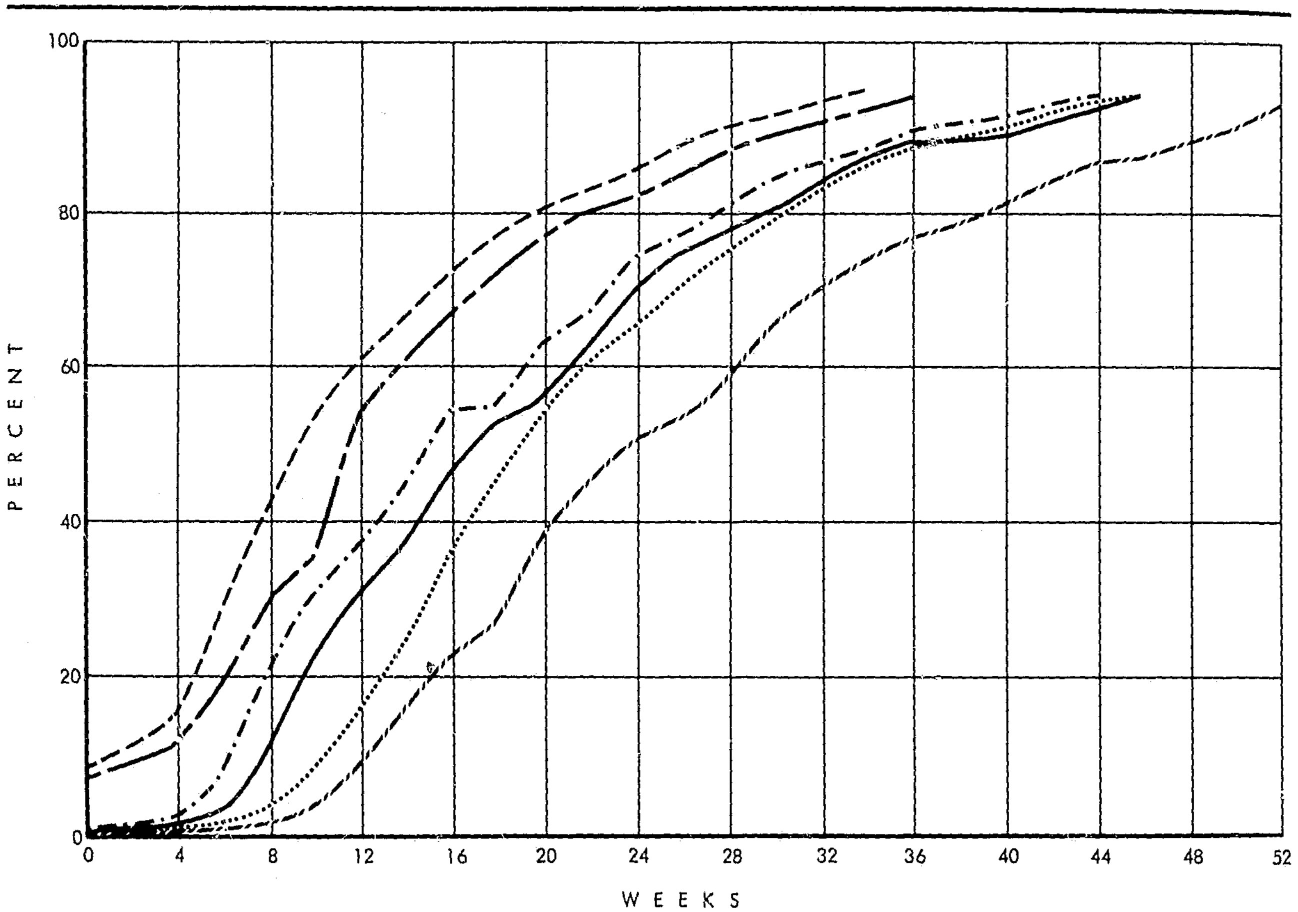
Table I–4.—Time (in weeks) between Arraignment and Disposition for Felony Defendants Whose Cases Were Filed in the District Court in 1965

Defendants who filed	Time between arraignment and nontrial disposition					Time between arraignment and trial disposition				
	No. of defendants	Mean	Percentiles			No. of defendants	Mean	Percentiles		
			50	80	100			50	80	100
No motions	481	9	7	14	48	[1] 108	14	11	22	47
1 motion	266	14	12	21	52	[1] 76	18	13	30	51
2 or more motions	163	19	16	27	66	[1] 81	23	22	32	59
All defendants	910	12	9	19	66	[2] 255	19	15	28	61

[1] Time measured to date trial began.
[2] Time measured to verdict.

[23] Motions for mental examinations are frequently filed in murder cases and take 60–90 days to be completed.

FIGURE I-4. TIMES TO TRIAL OR NONTRIAL DISPOSITION



STEPS	NUMBER OF DEFENDANTS	NUMBER OF WEEKS TO DISPOSITION		
		MEAN	MEDIAN	MAXIMUM
.... PRESENTMENT TO NONTRIAL DISPOSITION	631	22	19	74
-·-·-· PRESENTMENT TO TRIAL DISPOSITION	244	27	24	95
— — INDICTMENT TO NONTRIAL DISPOSITION	920	14	11	67
——— INDICTMENT TO TRIAL DISPOSITION	256	20	17	61
- - - ARRAIGNMENT TO NONTRIAL DISPOSITION	910	12	9	66
·—·— ARRAIGNMENT TO TRIAL DISPOSITION	255	19	15	61

4 months recommended in the proposed model timetable. These times are long despite the fact that most of the steps in the process require very little actual court time.[24] A defendant can be presented before a magistrate in a few minutes. A preliminary hearing takes between 15 and 30 minutes unless there is extensive cross-examination or the Government is forced to produce many witnesses. A grand jury can hear, consider, and vote on the average case in 30 minutes.[25] Arraignment takes a few minutes. Most motions can be heard in 10 minutes although some, in which evidence is taken, may require as much as half a day. A guilty plea usually takes no more court time than is required to pose and receive "yes" or "no" answers to a dozen questions.

The actual courtroom time for the defendant who pleads guilty prior to trial (approximately half of the defendants in the 1965 data) probably totals less than 1 hour, yet the median time from initial appearance to disposition takes 4 months. At least a quarter of this time is spent waiting for the return of the grand jury indictment. Some of the time after arraignment can be accounted for by case preparation and processing of papers. But for the average case this should be a matter of weeks not months. A prosecuting attorney has estimated that he would spend about a half day in preparation for an assault-with-a-deadly-weapon case involving two witnesses, and upwards to a week on a homicide case involving 20 witnesses. If motions are filed by the defense within 10 days after arraignment and heard and decided within a month thereafter, the average case should be ready for trial within 2 months after arraignment.[26]

The average elapsed time (including weekends and holidays) between the beginning of the trial and the verdict (for the 1965 felony cases examined) was 2 days for nonjury trials and 3 days for jury trials.[27] The courtroom days for trials in the District Court are Monday through Thursday with a reported average of 4–6 judges sitting on the criminal side in 1965. There was then, as there is now, a backlog of cases awaiting trial. In November 1966, it was observed that there were 302 cases on the reserve calendar, all motions having been completed but with some impediment preventing their going to trial, and 147 cases on the ready calendar with all impediments removed. It was also reported that in October 1966 the court had disposed of 40 cases with seven judges sitting in the criminal division. Further the backlog appears to be increasing; from July 1964 to July 1965 an increase of 20 percent was reported (from 449 to 610).[28]

SIMULATION OF THE PROCESSING OF FELONY CASES IN THE D.C. COURT SYSTEM

There are a number of alternative methods which suggest themselves and which might alleviate the delays and backlogs in the District Court for the District of Columbia. In order to pretest some of these and evaluate the feasibility of meeting a timetable such as that recommended by the Commission in chapter 5 of the general report, the Science and Technology Task Force developed a simulation of the processing of felony cases in the District of Columbia court system.

The two main reasons for using a simulation program are:

- ☐ It would be impractical to conduct actual experiments in the court system; such experiments can be run via the simulation.
- ☐ The results of the simulation can be used to pretest and evaluate the relative impact of various proposed policies and changes, such as firm timetables, increasing resources, etc.

Due to the limited time available for the development of the simulation, an established simulation language, IBM's General Purpose Systems Simulator (GPSS),[29] was selected. The language, although not primarily designed for simulating the court system, proved quite adequate and was flexible enough to handle all of the situations considered.

The resulting model, called COURTSIM, is described in more detail in a separate report.[30] Figure I–5 is a modified version of the flow diagram introduced in figure I–1. The circles represent processing units or "milestones" in the processing of a felon. For example, the circle labeled PRS represents the Court of General Sessions, U.S. Branch, where the defendant makes his first appearance before the courts. The circle labeled USC represents the U.S. Commissioner, where the defendant can also be presented. The arrows from one circle to another indicate the possible paths that the processing of a defendant may take; for example, from ARR (arrested) he may be presented to the U.S. Commissioner or his case may be discussed with the DAA (an Assistant U.S. Attorney, General Sessions Division) for possible presentment at PRS. Finally, the arrows going to squares represent possible stages in the process where a defendant may cease to be handled by the system due to a dismissal, reduction of the charge to a misdemeanor, "no paper," etc.

The numbers on the arrows represent the percentages of defendants leaving each processing unit which take the indicated path. These percentages were estimated for fiscal year 1965 from the data and by staff members of the President's Commission on Crime in the District of Columbia.

COURTSIM simulates a defendant entering the court system by generating an identification number and providing storage for relevant data including most serious charge, bail status, number of defendants in case, number of motions to be filed, date and time of entering system, etc. In the model the number of defendants arrested each day on a felony charge was a random variable distributed uniformly between 20 and 80. This results in surges and periods of slack, but averages 50 over the long run. Although one could easily introduce seasonal as well as daily variations in the average number of arrests per day, this was not done here. Disposition (termination at a square in figure I–5) is simulated by eliminating all references to the individual and recording, for statistical purposes, his total time in the system.

Both a clock and calendar are simulated. A workday of 5 hours was used,[31] the day being divided into 60 time intervals of 5 minutes each. During each time interval every processing unit does its work and defendants' cases proceed to the next unit if they are ready. When all the work for the time period has been completed the clock is incremented by one time unit and the work for the next unit of time commences. When the clock completes 60 units, the calendar is incremented 1 day and the clock is reset to the beginning of the next day.

At any given time a defendant is either being processed by some processing unit or waiting to be processed. Processing of a person is simulated by his occupying one of the allotted spaces at that unit for the amount of time he is to be processed. The capacity of a unit is equal to the number of people that can be simultaneously processed by it and is a function of the resources available for that unit. When all allotted spaces are occupied, admission is denied to other defendants ready to enter that unit. When a defendant has been processed at a unit, he departs to another unit, leaving the original processing unit free to accept another individual.

[24] The processing times are estimates based on those given by experienced lawyers and on observations made in the courtroom.

[25] In District of Columbia 8 cases are scheduled to be presented to the grand jury during a 4-hour period.

[26] Clearly an exception is the case where a mental examination is granted; this examination was taking upwards from 60 days in 1966. Fifteen percent of the defendants in 1965 were granted mental examination motions.

[27] These averages were calculated from the 1965 data by the President's Commission on Crime in the District of Columbia. The median values have not been determined.

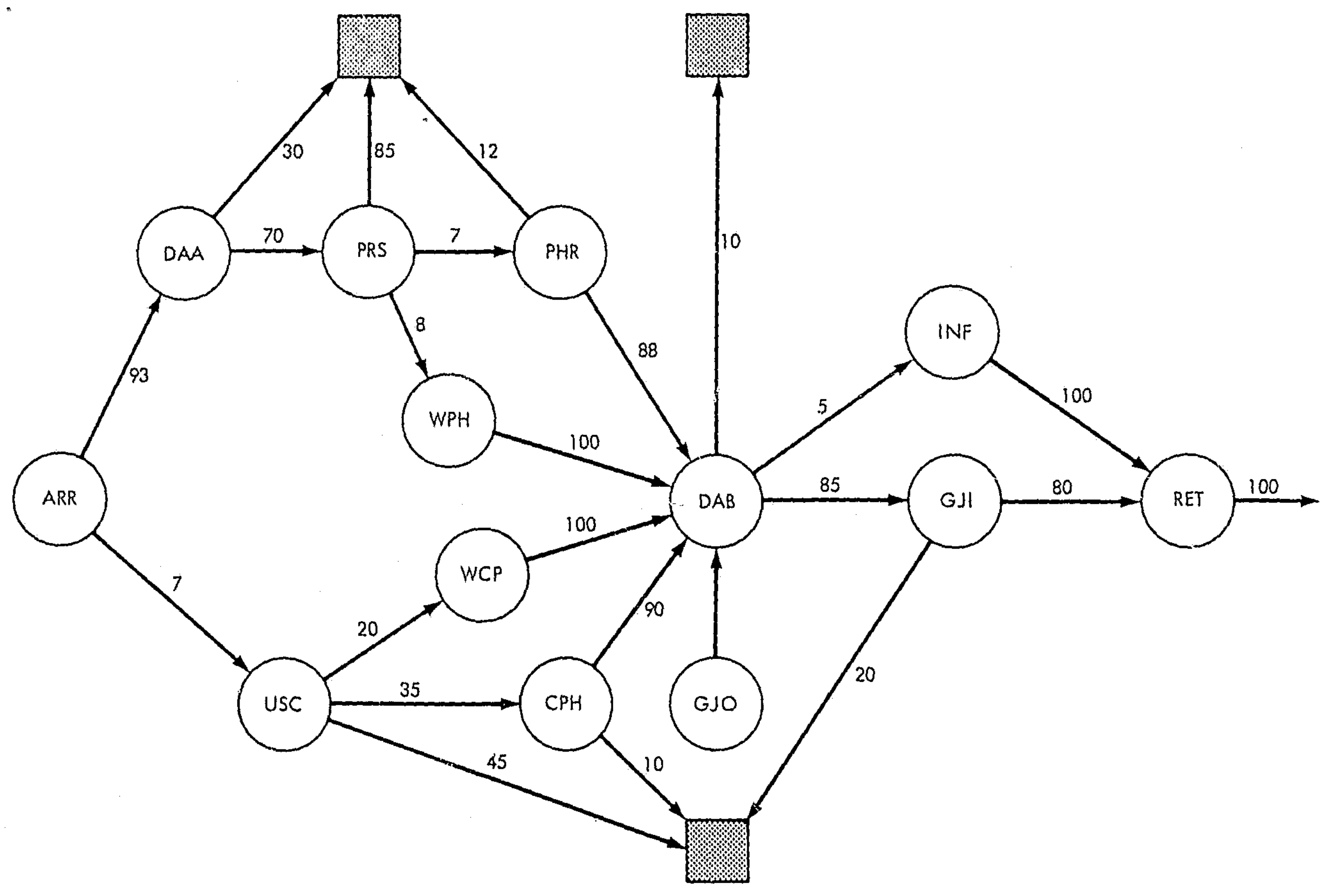
[28] Annual Report of the Director, Administrative Office of the U.S. Courts, 1965.

[29] IBM Application Program, "General Purpose Systems Simulator III, User's Manual," Form H20-0163-1, Technical Publications Department, White Plains, N.Y.

[30] "Court Operations: Data Analyses and Simulation of the Processing of Felony Defendants in the Trial Court System for the District of Columbia," now in preparation. The report will be available from the Clearinghouse for Federal Scientific and Technical Information of the National Bureau of Standards.

[31] No more than 5 hours per day was allocated to the actual processing of felony cases (as simulated here). Estimated hours per year for each processing unit are shown in table I–9.

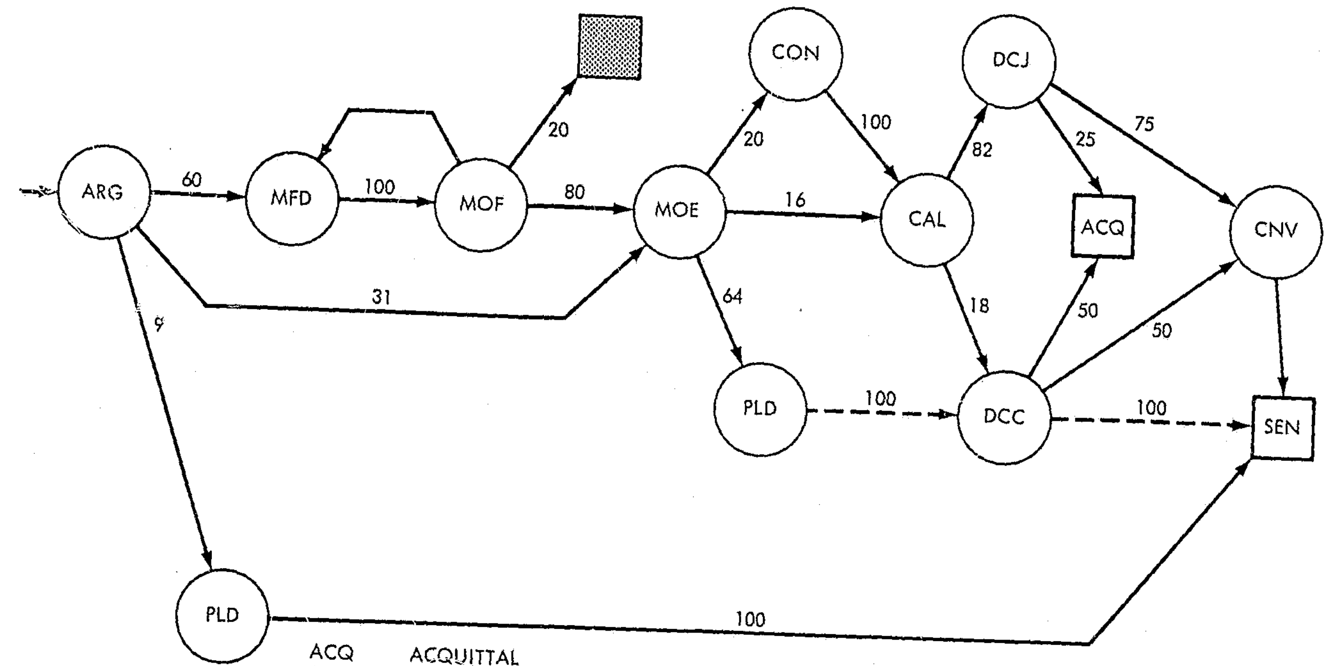
FIGURE I-5. FLOW DIAGRAM OF COURT SIMULATION



ARR ARREST
CPH PRELIMINARY HEARING AT U.S. COMMISSIONER
DAA ASSISTANT U.S. ATTORNEY, COURT OF GENERAL SESSIONS
DAB ASSISTANT U.S. ATTORNEY, GRAND JURY DIVISION
GJI GRAND JURY INDICTMENT
GJO GRAND JURY ORIGINALS
INF INFORMATION
PHR PRELIMINARY HEARING AT U.S. BRANCH, COURT OF GENERAL SESSIONS
PRS PRESENTMENT AT U.S. BRANCH, COURT OF GENERAL SESSIONS
RET RETURN OF GRAND JURY INDICTMENT OR FILING OF INFORMATION
USC PRESENTMENT AT U.S. COMMISSIONER
WCP WAIVED PRELIMINARY HEARING AT U.S. COMMISSIONER
WPH WAIVED PRELIMINARY HEARING AT U.S. BRANCH, COURT OF GENERAL SESSIONS

EXIT FROM SYSTEM

5 → PERCENTAGE OF DEFENDANTS FROM EACH STEP MOVING TO EACH OF THE SUCCESSIVE STEPS



ACQ ACQUITTAL
ARG ARRAIGNMENT
CAL CALENDAR
CNV CONVICTION
CON CONTINUANCE
DCC NONJURY TRIAL
DCJ JURY TRIAL
MFD MOTION FILING
MOE MOTIONS ENDED
MOF MOTION HEARD
PLD GUILTY PLEA
SEN SENTENCING

The amount of time a defendant spends at a given processing unit is determined by the characteristics of the actual process being simulated. At some places processing is estimated to require a fixed amount of time; at other processing units the time is randomly distributed within certain limits.

Table I-5 summarizes the conditions used in the simulation of the courts in 1965. It shows the estimated average capacity of each unit and the processing times required per defendant in that unit.

When a defendant arrives at a processing unit an attempt is made to process his case immediately. Any one of the following conditions can prevent immediate action and consequently result in his entering a queue:

1. The processing unit is currently being used to capacity.
2. The shared resources required at this processing unit are not available.
3. The unit is not open on this day of the week or hour of the day.

When the above conditions are no longer in effect, the processing unit is ready to accept another case from its queue. If the queue is empty, a portion of the processing unit's capacity remains idle until a defendant arrives for processing.

The results of the COURTSIM simulation are provided in statistical output form. These outputs consist of three types of statistics that are tabulated and computed during the computer run. They are associated with queues, processing units, and lengths of time required for defendants to move between selected points (stages) in the system. The reported queue data includes: average queue length, maximum queue length, mean length of time spent in queue. Information on processing units includes: average utilization, maximum utilization and average processing time. Statistical output on times between various units includes: percentiles, mean, and standard deviation of the elapsed times.

Table I-6 summarizes some of the COURTSIM features presently incorporated. The first column represents

Table I–5.—Assumed Processing Times and Capacities of Processing Units in Simulation Runs

Process	Processing unit	Units of resource time used (1 unit of time=5 min.)	Capacity	Comments
Arrest	ARR	....	....	
Presentment and Preliminary Hearings	USC	1	1	Presentment at the U.S. Commissioner (USC) 5 days a week. Preliminary hearing at the U.S. Commissioner (CPH) on Tuesdays and Thursdays only, with priority given to presentment.
	CPH	[1] 6, 3		
	DAA	3, 3	6	Case brought before Assistant U.S. Attorney, General Sessions (DAA), with presentment (PRS) and preliminary hearing (PHR) taking place at the U.S. Branch, Court of General Sessions, Monday through Saturday. Presentments have priority over preliminary hearings.
	PRS	1	1	
	PHR	6, 3		
Indictment	DAB	8	3	Case brought to the Grand Jury Unit of the U.S. Attorney's Office (DAB) where case is prepared for grand jury or information (INF) written. Grand jury processes case (GJI) and case returned to attorney (DAC), same as DAB, to be filed at District Court. GJI open Monday through Thursday. DAB, DAC, and INF open Monday through Friday.
	INF	1		
	DAC	12, 6		
	GJI	6, 3	1	
Arraignment, Motions, Continuances, Sentencing.	ARG	1	1	Arraignments (ARG) take place on Friday by Chief Judge in U.S. District Court. Defendant may plea guilty at this time (PLD_1). Motions are heard (MOF) on Friday, as are sentencings (SEN).
	PLD_1	....	....	
	MOF	3, 2	5	
	SEN	0	....	
	ZER	0	....	Motion is granted, resulting in zero delay (ZER), 14 days delay (FRT) or 60 days delay (SIX) or motion is denied (DEN) resulting in zero delay. Cases are allowed to go to trial 42 days after arraignment (MOE). Continuances (CON) follow MOE when they are granted.
	FRT	840	....	
	SIX	3600	....	
	DEN	0	....	
	MOE	....	....	
	CON	3000, 1200	....	
Trial	READY	....	....	(READY) of CAL block used to determine percentage of cases going to trial versus nontrial disposition.
	DCJ	See comment	5	Jury trials (DCJ) and nonjury trials (DCC_1) take place Monday through Thursday and the time required depends on type of trial and number of defendants in the case. Defendants who plead guilty after ARG require 5 minutes of court's time (DCC_2) as do defendants who plead guilty after READY (PLD_2).
	DCC_1	do		
	DCC_2	do		
	PLD_2	1		

[1] The notation 6,3 represents an average time of 6 units (30 minutes) with a spread of ±3 units (15 minutes).

a partial list of the computer statements or instructions used in COURTSIM,[32] the second column describes what the statement instructs the program to do, and column 3 illustrates the statement by examples. Not all of the potential features of the model are shown in this table. Other features include:

- ☐ The capability to process either defendants or cases.
- ☐ Allowing the various processors to be available only on given days of the week; for example, no trials on Friday, Saturday, Sunday. (Vacations and holidays can also be incorporated.)
- ☐ Changing the number of available processors at a processing unit as a function of workload, time of year, day or week, etc.
- ☐ Incorporating built-in delays such as exist in hearings of motions, mental examinations, etc.
- ☐ Assigning an Assistant U.S. Attorney, Criminal Division, to each case which is to be processed in the District Court. (Court-appointed, retained, legal aid or other defense attorneys can be assigned defendants.)
- ☐ Up to 100 different parameters can be associated with each defendant. Only 5 parameters have been used so far: date the defendant was indicted, whether or not he was on bail, the number of defendants in a case, the number of motions filed, and the most serious charge.

COURTSIM was used to simulate the flow of the 1965 felony defendants through the District of Columbia court system. Where data were not available for the model, estimates were obtained from knowledgeable officers of the courts and from direct observation. This was necessary particularly for the actual court processing times. The resources used in 1965 (numbers of judges, attorneys, etc.) were specified for COURTSIM. After several computer runs, the resulting output of COURTSIM matched sufficiently well the median times observed in the 1965 District of Columbia data. The small percentage of cases that necessarily require exceptionally long times between events in the system are not reflected in the model; however, these can easily be incorporated.

The COURTSIM model was run a total of 10 times

[32] The instructions also require other terms; for example, with the ADVANCE instruction one must include the advance time, which can be a fixed value or a random variable.

with the first run representing the processing of felony cases in the District of Columbia in the year 1965. The basic validation of the model was accomplished on the run called "Basic Revised." Here the actual number of defendants (or cases) handled at various processing units, as well as the average time from presentment (or arraignment to other stages of the process agreed with the District of Columbia data on felony cases in 1965. Table I–7 lists the 10 runs of COURTSIM along with a brief description of the modifications made.

Runs 1 and 7 represent simulations of the courts in 1965 with Run 1 (called 1965 Basic) resulting in longer average times to disposition than was observed in the 1965 data and Run 7 (Basic Revised) resulting in average times typical of those observed. The main difference between Runs 1 and 7 was in the amount of time spent in queue waiting to be processed through the Grand Jury Unit. Runs 2 to 6 are modifications of Run 1 (or 7). Runs 8–10 are simulations associated with changes made in the District Court in 1966, namely, rule 87. Run 8 represents the District Court system in the later months of 1966 in terms of the processing of defendants using the workload as observed in the 1965 data.

The results of several of the simulation runs are presented in table I–8 with a summary of a few of the more important time intervals starting from presentment of the defendant. The first row contains the median[33] times from the 1965 District of Columbia data. The other rows

Table I–6.—COURTSIM Processing Unit Capabilities

Computer statement	Computer operation	Example of the simulated court operation
Advance	Take time for the defendant to go to the next processing unit.	Time to go from presentment or preliminary hearing to Grand Jury Unit is one-half hour.
Priority	Assign the defendant a priority.	If defendant has a certain characteristic (example: he is in jail) let him be processed as soon as possible.
Queue Test	If the defendant cannot be immediately processed, put him in line according to his priority and test to see when he can be processed.	If it is not defendant's turn, the day is not Monday–Thursday, or the grand jury is not sitting, wait until all conditions are met.
Depart	Move the defendant to the processing unit to be processed when conditions allow.	Defendant's case is presented to the grand jury because the grand jury is available (he is at the head of the queue) and the day is Monday–Thursday.
Enter Test Advance	The defendant is processed, an amount of time determined by one or more tests on his parameter values.	Defendant's case is presented to the grand jury by an Assistant U.S. Attorney with accompanying witness(es). Average time for presenting case, grand jury deliberation and voting is one-half hour; defendant's characteristics can determine time.
Leave	Release the processor for other defendants.	Indictment is voted and the grand jury is available for the next case.
Assign	Modify the values of the parameter associated with defendant.	The defendant is assigned the number and type of charges brought in the indictment.
Test Transfer Function	Look ahead at workloads to decide where to send defendant and transfer according to the function.	Not applicable at indictment; used for example after arraignment to test the workload of the court and the associated queues and determine the percent who plead guilty, file motions, etc.

contain similar data obtained from the computer runs. In particular, the second row is a time summary of COURTSIM when used to simulate the conditions in 1965. Of interest is the fact that from presentment to arraignment takes approximately 7 to 8 weeks (observed both in the District of Columbia data and Run 7 of COURTSIM); some 5 weeks of this time was spent waiting for the return of an indictment in the simulation. When this delay was reduced to an average of 8 days, as a result of adding additional resources at the grand jury, COURTSIM yielded the times shown in the third row. Hence, the time awaiting return of the indictment was reduced by some 4 weeks.

The fourth row gives a lower bound on the average times if all transit times were eliminated, (i.e., as soon as one processing stage finishes with a defendant, he proceeds immediately to the next and waits only if the next processor is busy or is unavailable because of weekends). If such a condition had existed in the District of Columbia courts in 1965, a defendant would have taken an average of approximately 2 months after presentment to be ready for trial. Comparing these times with that of

Table I–7.—COURTSIM Computer Runs

Run No.	Features	Comments
1	Represents 1965 in terms of distribution of flow of defendants through the system. This run established the feasibility of the GPSS approach.	Too big a queue developed in the Grand Jury Unit during the initialization period which affected statistics in the run.
2	Same as above except: All felons had to have initial processing through the U.S. Commissioner's office.	This run showed that without increasing the number of commissioners, the felons can be handled in this fashion with no significant increase in time to disposition.
3	Same as 1 except: All felons had to have initial processing through the U.S. Branch of the Court of General Sessions.	Total time would be devoted to presentment and preliminary hearings with insufficient time for misdemeanor trials.
4	Same as 1 except: Percentage of guilty pleas is reduced from 57 percent to 36 percent.	Time to disposition increased by several weeks, and larger queues developed at trial time.
5	Same as 1 except: All unnecessary delays removed (queues not considered an unnecessary delay).	Time to disposition reduced by about 5 to 6 weeks.
6	Same as 1 except: Additional grand jury resources so as to eliminate queue at the grand jury.	Time to disposition reduced by approximately 6 weeks.
7	Same as 1 except: Queue in Grand Jury Unit reduced by approximately 2 weeks; trial times increased by 50 percent (to compensate for judge vacations, sickness etc.); all grand jury indictments returned on Mondays.	The results agreed closely with the 1965 data.
8	Same as 1 except: All arraignments are heard on second Friday after indictment; all motions heard on second Friday after filing; maximum of two separate motions hearings with first motion filed in less than 10 days after arraignment.	These modifications represent changes made in 1966 but do not include the calendar system used in late 1966. The time to disposition is reduced approximately 40 percent below that of Run 1.
9	Same as 8 except additional grand juries used to reduce queues in that unit.	An additional 5 to 6 weeks time cut off of Run 8.
10	Same as 8 except: 1966 calendar system used (cases to trial selected from ready calendar as a function of jail or bail, time since arraignment and U.S. Attorney); guilty pleas reduced to 30 percent.	Time to disposition about same as Run 8.

[33] Because of the few defendants whose times are exceedingly large, the mean times are larger than the median times and tend to distort the average. The means obtained from COURTSIM do not deviate greatly from median and hence are shown in table I–8.

the eighth row (the Administration of Justice Task Force recommended maximums), one can see that the timetable up to trial appears achievable.

The inputs to COURTSIM were modified to reflect some changes in rules and procedures of the District Court and their possible implications. These modifications include such factors as (1) decreased number of defendants pleading guilty as a possible result of the Bail Reform and the Criminal Justice Acts; (2) a delay in the entry of a guilty plea; and (3) the amendment of rule 87.[31] In addition, the current calendering system was incorporated. Cases were scheduled for trial with priorities given to jailed defendants and old cases provided there was no conflict with the case-assigned District Attorney. The 1965 input data was used, plus the above modifications. The results are tabulated in rows 6 and 7 of table I–8. Row 6 reflects the effects of enforcement of rule 87 on elapsed times after arraignment. Row 7 shows the simulated average times with one grand jury sitting regularly and with an additional grand jury sitting when necessary to keep the average waiting time in the Grand Jury Unit under 1 day. This Run also reflects the effects of maintaining the 1965 guilty plea rate of 55 percent. This last result again suggests that the timetable recommended by the Administration of Justice Task Force apparently can be met up to trial.

Other changes can be examined with minor modification of COURTSIM. For example, one could examine:

- ☐ What would happen to bottlenecks and time delays if a different calendaring system were introduced in the District Court?
- ☐ What would happen if more cases had to be procesed than presently estimated?
- ☐ What would be the effect of further changes in the scheduling of motions, sentencing and trial dates?

The above analyses indicate what can be done with a tool like COURTSIM in studying the impact on time intervals of changes in the court procedures. Associated with these analyses one must also look at the potential changes in the workload. Table I–9 shows the court workloads obtained from the various computer runs of COURTSIM. In Runs 4, 6, 7, and 10, about 30 percent of the estimated number of hours the U.S. Commissioner has available for presentments and preliminary hearings were used for this purpose. On the other hand, the U.S. Branch, Court of General Sessions, was used at approximately 90 percent of its available capacity in these simulation runs. (This Branch also tries misdemeanors.)

To see the effect of relieving the workload on the U.S. Branch, a run of COURTSIM (Run 2) was made with all felony defendants (about 6,300) having preliminary processing at the U.S. Commissioner's office. The condensed time and workload results are shown in tables I–8 and I–9. The computer run indicates that the time to process a defendant is not significantly increased, nor will the workload on the U.S. Commissioner be excessive, if all those arrested on a felony charge have preliminary proceedings before the U.S. Commissioner.[35] This tentative conclusion bears further investigation; however, these preliminary results suggest that such actions be considered. If all defendants were processed only at the U.S. Branch, General Sessions (Run 3), the workload would be excessive, with a slight increase in the times to reach various processing stages.

In summary, the 1965 data indicated that the median time to disposition, not including the time between conviction and sentencing, was 130 days for all defendants arraigned in that year. Of this time, approximately 40 days elapsed between preliminary hearing (or presentment, for those who waived preliminary hearing) and return of indictment. The computer simulation indicated that most of this time (35 days) was spent waiting for processing in the Grand Jury Unit. With a second grand jury and associated support the cases no longer piled up at this point and the 35-day wait to which all felony cases were subject was eliminated. About 70 percent of all felony cases filed in the court in 1965 were

Table I–8.—Representative Felony Processing Times (Average Number of Days)

COURTSIM Run \ Presentment to	Return of indictment	Arraignment	Guilty plea	Dismissal	End of motions [1]	Ready for trial	Time in Queue at Grand Jury Unit	Run
1965 data (median days)	40	53	107	134	148	[3] 167	?	......
1965 basic, revised	47	54	116	122	152	160	36	7
1965 basic with grand jury queue eliminated	16	24	90	102	......	127	8	6
1965 basic with grand jury queue eliminated and zero transit times	6	8	48	14	......	56	<1	5
1965 basic—All cases processed through U.S. Commissioner	61	64	131	140	......	164	45	2
1965 basic with rule 87; guilty pleas at 30 percent	38	40	68	58	70	88	31	10
1965 basic with rule 87; eliminated queue at grand jury	7	9	37	27	39	57	<1	9
Administration of Justice task force model timetable (maximum)	14	17	80	......	[2] 55	80	......	......

[1] At least 1 motion.
[2] First motion decided.
[3] To trial date.

[31] Amended rule 87 of the U.S. District Court for the District of Columbia provides that motions are to be filed within 10 days after arraignment and heard the second Friday thereafter; arraignments are to be held the second Friday after the return of the indictment.

[35] Under the present system of fees, and a maximum permissible yearly payment, there is little incentive to process additional cases once this maximum has been reached. In the District of Columbia, the U.S. Commissioner typically earns his maximum salary in the first 6 months of the year.

Table I–9.—Estimated Number of Hours/Year Required From Processor

Processing unit simulated	U.S. Commissioner	U.S. Branch, Court of General Sessions		Grand Jury Unit		U.S. District Court		
	Presentment and preliminary hearing	U.S. Attorney: Preparing, screening, etc.	Presentment and preliminary hearing	U.S. Attorney preparing [3]	Grand jury indictment	Arraignment	Motions and sentencing	Trials [2] (cases)
Estimated hours/year	1,300	4,675	1,560	3,900	1,040	260	1,300	5,200
Run No.:								
7	351	4,210	1,390	3,600	1,010	153	377	440
6	347	4,240	1,406	[1] 4,010	[1] 1,120	160	387	387
4	317	4,322	1,442	4,010	1,044	152	490	666
2	1,110	......	......	3,895	1,048	147	436	374
10	310	4,102	1,375	3,000	1,058	148	400	732
3	......	4,460	1,633	3,700	1,070	153	432	420

[1] Run 6 used the increased Grand Jury Unit resources of 25 percent discussed in the text.
[2] These are number of cases per year. The number of cases/year varies in Runs 2, 3, 6, and 7 because of the random function used in COURTSIM. The increased numbers in Runs 4 and 10 result from a decreased percentage of pleaders.
[3] The variations in preparation times from run to run is in part due to the different estimated processing times used.

disposed of by guilty plea or were dismissed on motion before the next major potential bottleneck in the system, awaiting trial. In the simulation, opening the bottleneck at the grand jury reduced the net time in the court for these 70 percent of the cases by the full 35-day wait at the grand jury.

Not all aspects of the COURTSIM runs were completely successful. For example, in the 1965 simulation, the cases that went to trial (i.e., 30 percent of the total cases) took approximately 5 weeks less when the bottleneck at the grand jury was eliminated. There was only a slight increase in the time it took to go from arraignment to trial disposition. The explanation for this probably lies in the nature of the data that were available for the simulation:

(1) *Number of Judges:* In 1965 an average of five judges was reported to have been sitting on the criminal side of the U.S. District Court for the District of Columbia.

(2) *Available Judge Hours:* The courtroom hours for trials were 10:00–12:30 and 1:45–4:00 (with two 10-minute breaks) 4 days a week; the fifth day was reserved for motions and sentencing.

From the above, it was assumed that 5,200 hours per year were available for trial of criminal cases in the District Court in 1965 (5 judges × 20 hours/week × 52 weeks/year).

(3) *Required Trial Time:* The available data on felony trial times were as follows:

(a) From the D.C. Crime Commission analysis of 1965 felony cases, an average of 2 days and 3 days for nonjury and jury trials, respectively (these represent upper bounds in that weekends are included and fractional days are considered full days).

(b) From the Administrative Office of the U.S. Courts, Annual Report 1965, table C8, the average nonjury trial time was computed to be 1.33 days, the average jury trial time was computed to be 2.8 days. (This is an overall average of all U.S. District Courts.)

In the simulation an average of 1.3 days was used for single defendant nonjury cases, 1.8 days for single defendant jury cases. These values were increased for multiple defendant cases (35 percent of the cases) for an overall average of 1.5 days and 2.2 days for nonjury and jury trials, respectively. These times do not include Friday, Saturday, and Sunday for cases that ran over the weekend. When that time is included, an average of 2 days and 3.6 days for nonjury and jury trials, respectively, resulted in the simulation.

(4) *Number of Trials:* In the simulation a total of 440 cases went to trial; this compares with 407 reported for the U.S. District Court for District of Columbia in fiscal year 1965 in the Administrative Office report (table C7).

Based on (1) to (4) above the simulation indicated that the total number of trial hours required in 1965 was 90 percent of the trial hours assumed available. By reducing the queue at the grand jury a temporary surge was created and increased the load on the judges by an additional 15 percent. The slight queue resulting from this did not significantly increase the total average time for trial disposition.

In summary an average of 25 percent time reduction was observed for the combined trial and nontrial dispositions. This reduction is due to the fact that there was only a small increase in time for those who had trial dispositions (due to the temporary surge by relieving the queue at the grand jury) under the assumptions in the simulation.

Further, if one required that all motions be filed and heard within 17 days, (Run 8) in association with the increase in the Grand Jury Unit resources, the simulation results indicated that the mean time from initial presentment to trial disposition was reduced from over 5 months to 3 months.

There appears to be some evidence that since 1965 there have been increasing demands on the courts. This might be attributed to several recent changes, e.g., the Bail Reform Act and the Criminal Justice Act. The study in question did not assess these changes in detail. Furthermore, the procedure for scheduling cases for trial has been modified, and the percentage of cases disposed of by guilty pleas has reportedly declined.

During the period from 1960–63, the yearly averages were 1,093 filings and 1,077 terminations, a close balance. The court's processing rate over the period 1964-66 averaged about 1,200 cases per year. From 1963–66, filings increased at a rate of over 100 cases per year to a level of 1,453 in 1966. The backlog of pending cases, which was stable at an average value of 480 in the period 1960-64, climbed to 610 in 1965 and 913 in 1966. This would seem to offer strong evidence that significant changes occurred in the District of Columbia courts during the 1965–67 time period. Because of the above, a detailed analysis of the courts in the present time period would be required to evaluate the court's resources necessary to handle the current workload. Unfortunately, the data required for this analysis and simulation are not readily available and for certain types of data (e.g., processing time) are not being collected. The computer simulation tool developed here can be used in this evaluation provided that these data are made available.

The data deficiencies which have limited all the Task Force's efforts have also hampered the court analyses, even though the District of Columbia criminal felony data is far more extensive than any examined. Some of the required data are not available in court records nor in the present criminal jackets or records. To alleviate this deficiency:

(1) Data should be collected not only on those cases for which return of indictments are made but also on those cases (or defendants) which drop out from the felony processing route. This can be accomplished by establishing a felony disposition file made up of jackets which store the information on each case until disposition. Each jacket should contain all the required information on the case, including all the data presently being collected in the felony jackets as well as the following types of information:

Amount of court time spent at each processing stage, e.g., length of time for preliminary hearing.

Number of witnesses used at each processing stage.

The date the case was ready to be processed and the date it actually was processed; e.g., when the case was handed to the Grand Jury Unit for processing, when it was presented, and when the indictment was voted.

(2) The jackets should be designed and coded so as to minimize the problems associated with conversion to computer tapes or cards. To achieve a maximum of uniformity and consistency, the jacket design should use a multiple-choice selection layout. Such a design has been established by the Administrative Board of the Judicial Conference of the State of New York. A felony disposition jacket should be formatted so as to be applicable on a nationwide basis using the New York approach as a model guide. A misdemeanor disposition record should be designed concurrently with the same features.

No data have been collected to investigate the possible cost for data collection or those costs associated with the changes investigated in the court system. Obviously, such analyses are required in order to determine which of several proposed changes achieves a desired level of improvement, such as meeting a model timetable, most economically. This general approach, called cost-effectiveness analysis, has become standard within the Department of Defense and has applicability to criminal justice as well, as discussed in chapters 2 and 5. One estimate made indicated that an additional increase of 25 percent of manpower resources in the Grand Jury Unit (one U.S. Attorney, one clerk, both full time, and one grand jury, one quarter of the year) would cost approximately $50,000.

Some conclusions and recommendations can be drawn based on the results of the analyses of the District of Columbia felony data and the running of COURTSIM. Some require more detailed analyses based on accurate measures of processing times. Others call for close, coordinated work between the court staff and a research team to refine, examine, and test some of the tentative conclusions.

Based on the examination of the processing of felony cases in the District of Columbia:

☐ Serious consideration should be given to using the U.S. Commissioner's office for the preliminary processing of felony defendants, thereby relieving the workload on the U.S. Branch of the Court of General Sessions. Readjustment of resources in the U.S. Attorney's Office and additional hearing days at the U.S. Commissioner would probably be required.

☐ Based on the above analyses, the elapsed time between presentment and return of indictment can be reduced from an average of 6 weeks to 2 weeks by eliminating the queue at the grand jury. This would require some additional hours by the grand jury, a more expeditious manner of preparing and processing the indictments and a review of the additional U.S. Attorney and clerical manpower requirements. Relief of this delay at the grand jury will have an impact on the queue that exists for trial. A close examination of the extent to which court rules for filing motions and granting motions are enforced, the practicality of extensive use of pretrial hearings, together with an analysis of the number of hours and trial days available would reveal the impact of relieving the grand jury queue on the total time before disposition for defendants going to trial.

☐ The timetable recommended by the Administration of Justice Task Force appears to be reasonable for the District of Columbia court system and could be used as a standard against which to measure delay.

☐ An intensive data collection effort should be instituted in the District of Columbia court system in order that the present simulation can be refined and other analyses performed. This data collection should record the time, in minutes and hours, not just days, that is actually spent in processing the defendant, by what court official or staff member this is done, and what action is taken. This should cover all cases from time of arrest to final disposition, not just those cases that are commenced in District Court. Such an effort would not be unduly burdensome; statistical sampling techniques can be used, forms prepared and those persons already involved in the system could record the necessary information.

☐ The COURTSIM model can be refined with better data and in close coordination with court officials; it should be pursued and imbedded in the court system to provide court management with a useful tool. Furthermore, it has the potential for including processing of misdemeanor cases in the Court of General Sessions.

The analysis of court operations, although focused on delay in the proceeding of felony defendants in the District of Columbia, leads to recommendations for court operations in general:

☐ A uniform data base should be established in order that meaningful and useful analyses can be accomplished to isolate problem areas and recommend solutions on a county, State or National level.

☐ The COURTSIM model should be extended to several large urban areas as a pilot study to determine its applicability to other court systems and its overall usefulness. Concurrently with these pilot studies, a more sophisticated computer language should be developed to increase the efficiency and flexibility of the simulation program.

The Task Force has focused on delay and workload. Clearly there are other areas of equal importance that deserve close examination: updated management procedures administered by a court administrator; evaluation of the cost and manpower requirements associated with potential changes in the system; organizational changes in some courts; and the layout of physical facilities.

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PROJECTED PERCENTAGE OF U.S. POPULATION WITH CRIMINAL ARREST AND CONVICTION RECORDS

by Ronald Christensen

Contents

The object of this note is to provide an estimate of the percentage of the future U.S. population which will have a criminal arrest record resulting from at least one non-traffic arrest, and of the percentage which will have a criminal conviction record resulting from such an arrest. Making such estimates requires assumptions about how trends will develop in the future. In general, we make the assumption of "steady state," or that the current situation will continue into the future. This is not intended to suggest that the current situation will necessarily continue, but that the projections will be as indicated if it does continue. If, for instance, the projection of arrest probability is viewed as undesirably high, then that would suggest a reconsideration of the factors making it so high. The value of such projections lies in stimulating such considerations much more than in a literal prediction of the future.

Making these projections also requires various data on such parameters as number of arrests, population distribution, and the virgin arrest ratio (i.e., the portion of arrestees who have never before been arrested). Some of these parameters, especially the virgin arrest ratio, are difficult to estimate accurately from available data. Wherever possible, conservative estimates have been used. Since the validity of any analyses such as those reported here are inherently limited by the available data, we hope that this paper will stimulate the collection of more accurate and complete data.

ARRESTS

The arrest data [1] used are based on crimes reported in the FBI's Uniform Crime Reports (UCR) for 1965. These crimes are listed together with arrest totals for the reporting agencies:

Offense charged	All ages	Ages under 18	Ages over 18
Total	5,031,393	1,074,485	3,956,908
Criminal homicide:			
Murder and nonnegligent manslaughter	7,348	635	6,713
Manslaughter by negligence	2,815	196	2,619
Forcible rape	10,734	2,245	8,489
Robbery	45,872	13,813	32,059
Aggravated assault	84,411	12,950	71,461
Burglary, breaking or entering	197,627	102,472	95,155
Larceny, theft	383,726	210,469	173,257
Auto theft	101,763	63,596	38,167
Total of above offenses	834,296	406,376	427,920
Other assaults	207,615	31,948	175,667
Arson	6,187	4,031	2,156
Forgery and counterfeiting	30,617	2,962	27,655
Fraud	52,007	1,796	50,211
Embezzlement	7,674	275	7,399
Stolen property: buying, receiving, possessing	19,060	6,720	12,340
Vandalism	89,668	68,785	20,883
Weapons: carrying, possessing, etc	53,585	10,985	42,600
Prostitution and commercialized vice	33,987	839	33,148
Sex offenses (except forcible rape and prostitution)	58,205	14,097	44,108
Narcotic drug laws	46,069	5,345	40,724
Gambling	114,294	2,561	111,733
Offenses against family and children	60,981	648	60,333
Driving under the influence	241,511	1,937	239,574
Liquor laws	179,219	48,456	130,763
Drunkenness	1,535,040	25,912	1,509,128
Disorderly conduct	570,122	93,472	476,650
Vagrancy	120,416	7,894	112,522
All other offenses (except traffic)	531,970	156,310	375,660
Suspicion	76,346	20,612	55,734
Curfew and loitering law violations	72,243	72,243	----------
Runaways	90,281	90,281	----------

During the last 5 years, the probability of being arrested as a function of age has been increasing for each age group of the population, the increase being most pronounced for the younger age groups. However, for purposes of this calculation, we will make the conservative assumption that the age-specific arrest probabilities for future years will remain the same as they were in 1965. This tends to underestimate the probability of eventual arrest. Yet, this probability will be found to be strikingly high even with this and other conservative assumptions.

[1] "Crime in the United States, Uniform Crime Reports—1965"; July 28, 1966, p. 112. Covers 4,062 reporting agencies which represented an estimated 1965 population of 134,095,000.

METHOD USED

Suppose P_t is the probability of a person in the class of interest being arrested as a t-year-old. Then the probability of an individual in this class being arrested during his life is

$$P = P_0 + (1-P_0)P_1 + (1-P_0)(1-P_1)P_2 + \ldots$$

$$= \sum_{t=0}^{T} (1-P_0) \ldots (1-P_{t-1})P_t$$

$$= 1 - \prod_{t=0}^{T} (1-P_t)$$

where T is a large number, say 90 years, after which age few people are arrested for the first time.

However, suppose p_t is the probability of an individual in the class of interest being arrested *for the first time* as a t-year-old. Then

$$P = \sum_{t=0}^{T} p_t$$

The two equations are, of course, equivalent since

$$p_t = (1-P_0) \ldots (1-P_{t-1})P_t$$

Our model is steady state in the sense that we assume that the age-dependent arrest probabilities for 1965 carry forward unchanging into the future.

In figure J–1, those persons 5 years old in 1965 fall in the lower left-hand shaded box in the figure. (We use 5-year-olds since this is approximately the age at which some arrests begin to occur.) As time progresses, this group advances up the series of diagonal boxes. Because of the steady state assumption, all boxes along a horizontal line represent identical arrest probabilities. Thus, we refer back across to the associated box in the 1965 data base to establish the appropriate p_t.

Let V_t be the number of first arrests in the t^{th} box and M_t be the total number of people in the t^{th} box. Then

$$p(t) = \frac{V_t}{M_t}$$

is the probability of first arrest for someone in the t^{th} box.[2]

The proportion of the 5-year-olds who, from survival statistics, will live to be t years old is L_t (see table J–1). Thus, the probability of a person who is 5 years old today being first arrested as a t-year-old is $p_t = L_t p(t)$.

Summing, we get:

$$\sum_{\tau=5}^{t} p_\tau$$

as the probability of someone 5 years old today being arrested by the time he is a t-year-old. The summation is proper since being arrested for the first time at one age and being arrested for the first time at a different age are disjoint events.

FIGURE J-1. THE POPULATION MODEL

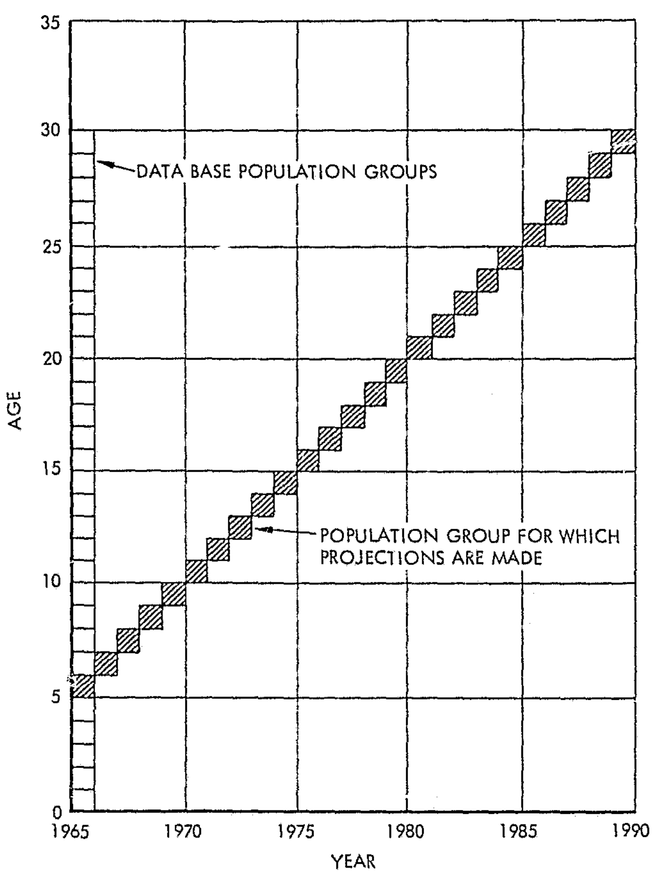


Table J–1.—Probability of a 5-Year-Old Surviving to Age t

Age (t)	Probability (L_t) of survival	Age (t)	Probability (L_t) of survival
5	1.0000	40	0.9578
10	.9978	45	.9403
15	.9957	50	.9135
20	.9905	55	.8727
25	.9843	60	.8143
30	.9777	65	.7341
35	.9694	70	.6266

Source: 1966 Statistical Abstract.

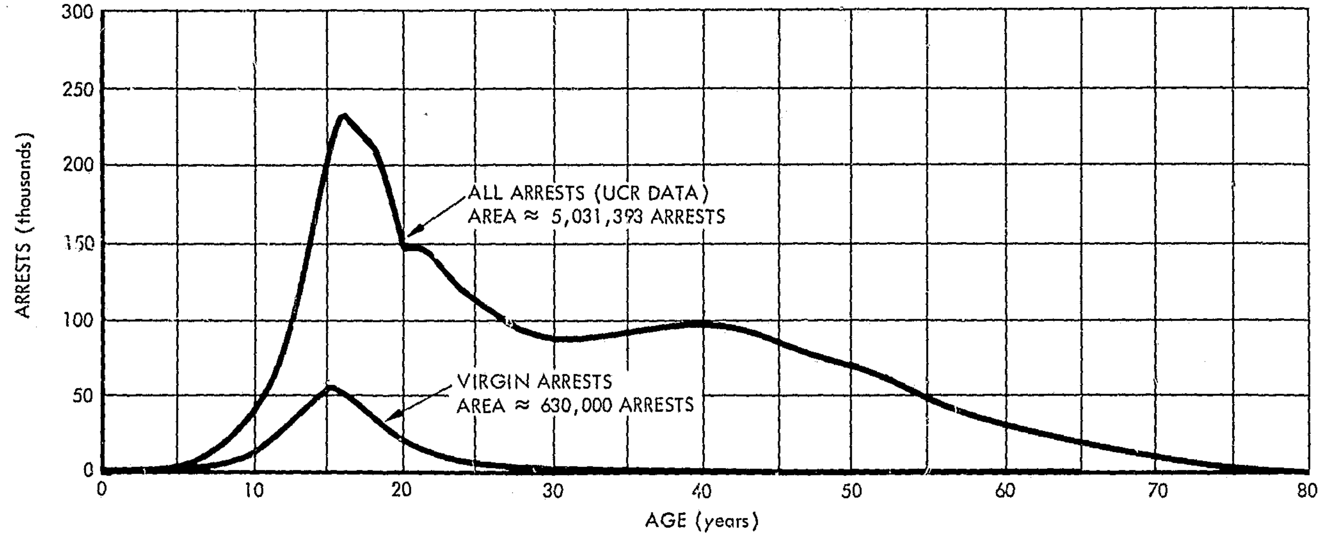
DATA ON ARRESTS AND VIRGIN ARREST RATIO

Figure J–2 shows the distribution of the total number of arrests in 1965 by age,[3] as recorded in the 1965 UCR. The total area below the top curve integrates to a total of 5,031,393 arrests by reporting agencies servicing a population of 134,095,000 (about 69 percent of the total census estimate of 194,400,000 for 1965). We will assume that the crime characteristics of this population

[2] The denominator must be the total number of people in the t^{th} box, and not just those never arrested at a younger age, in order to obtain the cumulative probability by simple summation as we do below. If we reduce the denominator as stated, we get the conditional probability of a t-year-old being arrested given that he has never been arrested. The ratio V_t/M_t, on the other hand, is the joint probability of a t-year-old being arrested and never having been arrested before. Not only would using the conditional probability rather than the joint probability lead to a more cumbersome formulation, it would require data presently unavailable; namely, data on the arrest history of the population as a whole as well as on those arrested in 1965.

[3] An interesting anomaly is the unusual secondary peak in the rates of arrest for various crimes of reported 18-year-olds and the corresponding depressions for reported 17-, 19-, and 20-year-olds in fig. J–2. (The peak is even more pronounced for graphs drawn by crime type.) It remains to be seen whether this is a real phenomenon or a peculiarity in reporting the age of arrestees.

FIGURE J-2. 1965 ARRESTS BY AGE FOR ALL NONTRAFFIC OFFENSES



are representative of the United States in general, although we will later correct for the relative disproportion of urban coverage by the reporting agencies.

The next problem is to find the fraction of all arrests which are virgin arrests; i.e., arrests of individuals who have never been arrested before.[1] This datum is crucial to the calculation, and has proved most difficult to come by. Almost all potential sources for this datum proved to be insufficiently complete, resulting in an unrealistically high figure. For example, according to the Bureau of Criminal Statistics for California, about 32 percent of the arrests in San Mateo County between July 1, 1961, and June 30, 1962, were of individuals with no prior record.[5] A breakout of this percentage by crime type is given as follows:

Felonies	Virgin Percent	Misdemeanors	Virgin Percent
Homicide	25.0	Assault	38.9
Robbery	14.8	Petty theft	50.0
Aggravated assault	49.1	Drunk driving	36.5
Burglary	25.8	Checks	38.9
Grand theft, except auto	41.7	Drunk	22.5
Auto theft	23.7	Disturbing peace	35.4
Forgery of checks	35.3	Malicious mischief	50.0
Rape	40.0	Sex offenses	49.0
Other sex	66.7	Other misdemeanor	36.0
Narcotics	10.0		
Other felony	24.3		

These included both felony and misdemeanor arrests, and the misdemeanor arrests included roughly the usual proportion of such things as arrests for drunkenness. Aside from the fact that San Mateo is not representative of the nation, the principal reason for the extremely high figure is that juvenile arrest was not included either as a criterion for inclusion in the sample or as a part of "prior record" in the data. It covered only adult records of adults arrested during the period. Almost one-quarter of all arrests are of persons under 18 years of age.

The FBI criminal history file,[6] which yields a virgin arrest ratio of about one-quarter, is also not applicable to this problem. First, it includes only fingerprintable offenses (even not all of these), and therefore excludes drunkenness, etc., from almost all jurisdictions. Second, it is a file of certain arrestees rather than a representative sample of all arrests during some given period. Similar remarks apply to State criminal history files, such as the New York State file which, by counting virgin arrests in arrest reports received, was found[7] to yield a ratio of about one-third for the year 1965.

On September 22, 1966, a random sample of arrest records was taken from the District of Columbia Metropolitan Police Communications and Records Bureau criminal history file. The fraction of these arrests which were of individuals with no prior record in the file is shown in figure J-3 as a function of the year of the arrest. The downward trend seems to suggest that the file has been becoming more complete over the last 5 years (although it is probably also due in part to the fact that the percentage of the population with no record has been decreasing as the arrest rate has been increasing). Here again we get a ratio somewhere between one-quarter and one-third due to such factors as the absence of juvenile records in the file and the absence of records from other jurisdictions.

The only source of data which proved sufficiently complete was a study of 1965 juvenile referrals and adult arrests in the District of Columbia based on probation de-

[1] In the steady state model (but allowing arbitrary population-age distribution), the virgin arrest ratio r is exactly the inverse of the average number of arrests a during the lives of those arrested at least once:

$$r = \frac{\text{number of virgin arrests in any year}}{\text{total number of arrests in the year}} = \frac{\text{number of people arrested in a long-time period}}{\text{total number of arrests in the long-time period}} = \frac{1}{a}$$

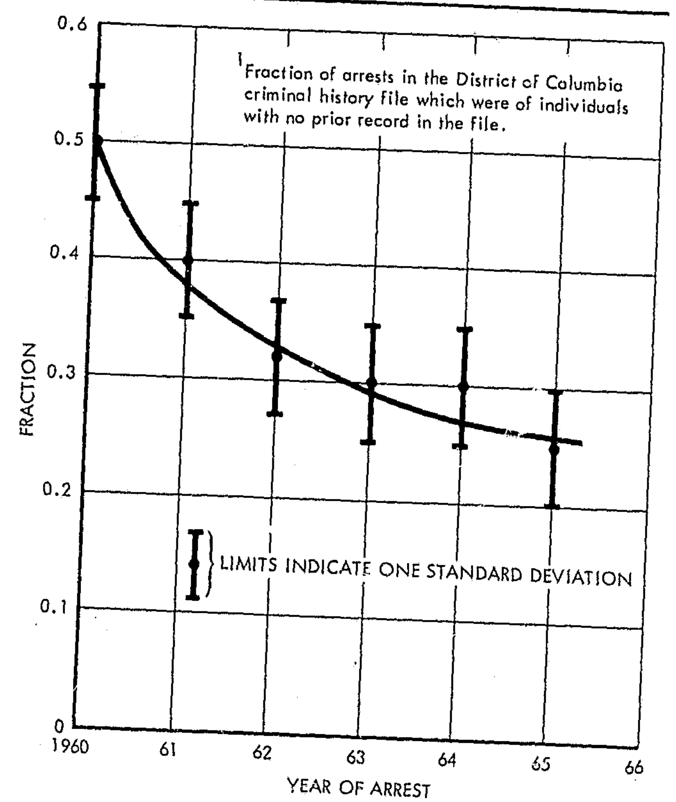
For example, if the average arrest career is 8 arrests, then on the average 1/8 of all arrests in any given time period are of persons never arrested before.

[5] Bureau of Criminal Statistics, California Department of Justice, "San Mateo County Statistical Reporting Project," 2700 Meadowview Rd., Sacramento, Calif. For the period 1962–63, the number was about 29 percent.

[6] UCR, 1965, p. 28.

[7] Private communication, September 1966.

FIGURE J-3. FRACTION OF VIRGIN ARRESTS IN THE DISTRICT OF COLUMBIA CRIMINAL HISTORY FILE [1]



partment investigations.[8] For juveniles, it was found that about 39 percent of those referred to juvenile court had no previous referrals.[9] For adults, it was found that about 15 percent of the white arrestees and 8 percent of the Negro arrestees who were convicted of a felony in 1965 had no prior arrest record for either a misdemeanor or a felony.[10] These last figures are probably lower than the national averages both because District of Columbia, being urban, is not a truly representative area, and because this sample is probably biased toward the repeater, being of convicted felons only rather than all arrestees.

According to the UCR, 29 percent of the U.S. arrestees in 1965 were Negroes, while 71 percent were whites and others. Thus, projecting the above fractions onto the nation as a whole, we obtain:

$$(0.71)(0.15) + (0.29)(0.08) = 0.13$$

as an estimate of the fraction of all adults arrested in 1965 who never had a prior arrest.

Now we must deal with the fact that some persons were arrested more than once in 1965. Let us define:

N_A = Number of arrests in 1965
N_I = Number of individuals arrested in 1965
N_V = Number of virgin arrests in 1965

Then, for juveniles:

$$\left(\frac{N_V}{N_A}\right)_{\text{Juveniles}} = \frac{\left(\frac{N_V}{N_I}\right)_{\text{Juveniles}}}{\left(\frac{N_A}{N_I}\right)_{\text{Juveniles}}} \approx 31 \text{ percent}$$

using the figures:

$$\left(\frac{N_V}{N_I}\right)_{\text{Juveniles}} \approx 39 \text{ percent}$$

and:

$$\left(\frac{N_A}{N_I}\right)_{\text{Juveniles}} \approx {}^{11}1.25$$

For adults:

$$\left(\frac{N_V}{N_A}\right)_{\text{adults}} = \frac{\left(\frac{N_V}{N_I}\right)_{\text{adults}}}{\left(\frac{N_A}{N_I}\right)_{\text{adults}}} \approx 7.6 \text{ percent}$$

using the figures:

$$\left(\frac{N_V}{N_I}\right)_{\text{adults}} \approx 13 \text{ percent}$$

and:

$$\left(\frac{N_A}{N_I}\right)_{\text{adults}} \approx {}^{12}1.7$$

This gives us estimates of the virgin arrest ratio for two different age groups, those below 18 and those 18 and above. (Although the juvenile-adult dividing line varies from jurisdiction to jurisdiction and can even depend upon the case within a jurisdiction, we will use the average of about 18 years of age for purposes of these computations.) However, if we want to know the probability of an individual acquiring a record by the time he reaches a given age, then we must know explicitly how the ratio

[8] Report of the President's Commission on Crime in the District of Columbia; 1966; appendix.

[9] Ibid, p. 490.

[10] Ibid, p. 488.

[11] Based on data from the 52d Annual Report of the County Court of Philadelphia, 1965, pp. 111 and 131.

[12] A conservative estimate of this number can be obtained as follows: Let a= average lifetime number of arrests of persons arrested at least once in lifetime, and T_a=average arrest career (average number of years between first and last arrests of persons arrested at least once). Then the average number of arrests per year during an arrest career is a/T_a. If all we know is that an individual was arrested at least once in 1965, our estimate of the number of additional times that individual was arrested during that year should be no greater than

$$\frac{a-1}{T_a}.$$

Since $N_A - N_I$ equals the number of persons arrested in 1965 times the average number of "additional" arrests per person in 1965, we get an upper bound of

$$\frac{N_A}{N_I} = 1 + \frac{N_A - N_I}{N_I} = 1 + \frac{N_I\left(\frac{a-1}{T_a}\right)}{N_I} = 1 + \frac{a-1}{T_a}$$

At this point, we imagine leaving a as a parameter, and solving for it by setting $r=1/a$ when we finally compute the overall virgin arrest ratio. Using $T_a \approx 10$ (FBI criminal career data), this gives the equation:

$$1/a = \frac{0.31\,(N_A)_{\text{Juveniles}} + \frac{0.13 (N_A)_{\text{Adults}}}{0.9+0.1a}}{(N_A)_{\text{Juveniles}} + (N_A)_{\text{Adults}}}$$

Inserting the 1965 UCR values:

$$(N_A)_{\text{Juveniles}} = 1,074,485$$
$$(N_A)_{\text{Adults}} = 3,956,908$$

The solution is $a \approx 8$.

This gives us:

$$\left(\frac{N_A}{N_I}\right)_{\text{Adult}} \approx 1.7.$$

of first arrests to all arrests varies with the age of the individual. We know that it is generally a decreasing function of age. But there appears to be no data from which we can directly determine the functional dependence. However, we do have sufficient information to construct a function which will be sufficiently accurate for our purposes. The data points on figure J–4 represent the fraction of juvenile referrals, by age, in the Philadelphia County Court in 1965 with no prior court record. Although these data refer to court records rather than arrest records, they are still useful in approximating the shape of the curve in the 6- to 17-year-old range, and providing a basis for estimating its shape outside this range.

We now seek a curve, representing the ratio r_t as a function of t, of this general shape which satisfies the constraints:

$$\frac{\sum_{t=1}^{17} r_t N_t}{\sum_{t=1}^{17} N_t} = 0.31$$

$$\frac{\sum_{t=18}^{90} r_t N_t}{\sum_{t=18}^{90} N_t} = 0.076$$

where:

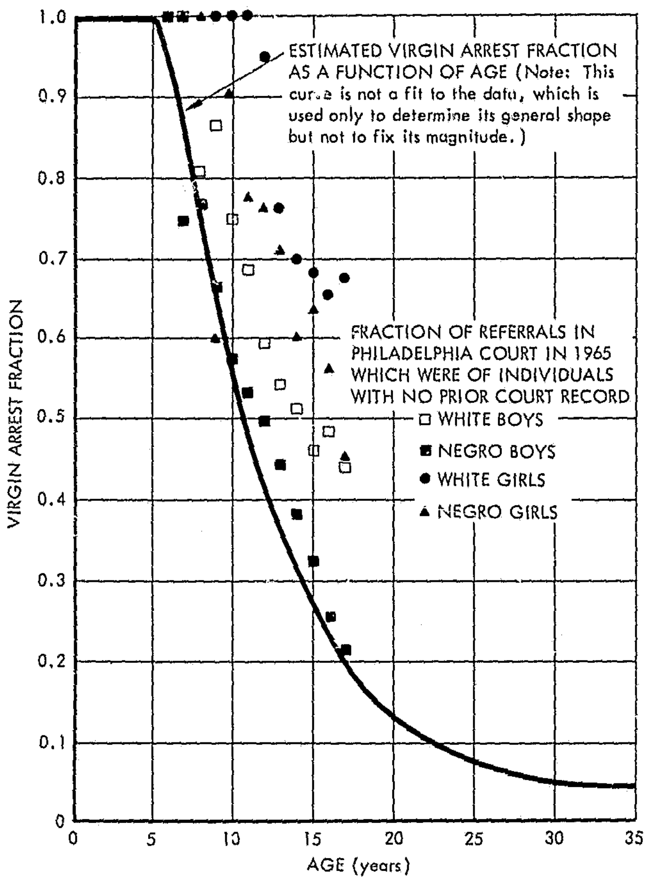
N_t = Number of UCR arrests in 1965 of t-year-olds

A curve which meets these requirements is also shown in figure J–4.

Having found r_t, we can plot $r_t N_t$ as a function of t. This is the lower curve on figure J–2, representing the number of virgin arrests in 1965 as a function of age of individuals arrested. The number of virgin arrests is about 630,000 out of a total of 5,031,393, giving an overall virgin arrest ratio of about one-eighth, or 12.5 percent.

In general the age-specific ratio, r_t, for any given age t, is highest for white females, next highest for Negro females, next for white males, and lowest for Negro males. However the available data is insufficient to enable us to estimate very reliably the difference in the functional form of r_t for each of these four categories. Instead when we come to the end of the calculation we will simply correct the weighted average to 0.15 for whites and 0.08 for Negroes, in accordance with the District of Columbia Crime Commission data. Since males constituted the bulk, 94.1 percent, of the arrestees in that sample, these figures are really estimates for males and not for females. Data for 1965 from the County Court of Philadelphia indicates that the virgin arrest ratio is about two times as great for females as for males. We will also make this correction at the end of the calculation.

FIGURE J-4. VIRGIN ARREST FRACTION AS A FUNCTION OF AGE



ARREST PERCENTAGES

Figure J–5 shows M_t, the number of t-year-olds in the United States in 1965, as a function of age t, the total population being about 194,400,000.

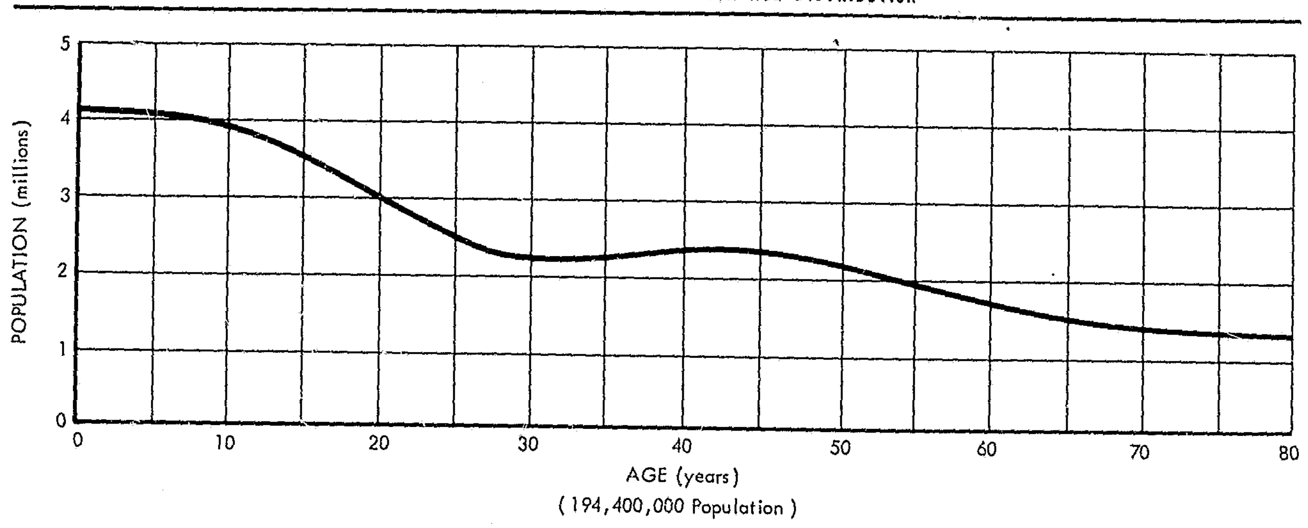
The curve of figure J–6 shows the probability of an individual being arrested during the year for the first time in his life as a function of age. It is calculated by the formula:

$$p(t) = \left(\frac{\text{UCR first arrests in 1965 of } t\text{-year-olds}}{t\text{-year-olds in United States in 1965}}\right) \times \left(\frac{\text{1965 United States population}}{\text{1965 UCR population}}\right)$$

$$= \left(\frac{r_t N_t}{M_t}\right) (1.45)$$

The fraction of total 1965 UCR arrests which were of males was 0.881 and of females was 0.119. Thus, the

FIGURE J-5. 1965 U.S. POPULATION AGE DISTRIBUTION



cumulative probability of the child born in 1965 having an arrest record by the time he is T years old is given by:

Male:

$$P_m(T) \approx \sum_{t=1}^{T} \frac{0.881}{0.492} p_t$$

Female:

$$P_f(T) \approx 2 \sum_{t=1}^{T} \frac{0.119}{0.508} p_t$$

where:

$$p_t = L_t p(t)$$

As mentioned previously the factor of 2, to correct the female virgin arrest ratio, is included in the above expression for females.

These curves are plotted on figure J–7. They show, for example, that the probabilities of eventual arrest by the time of life-expectancy age to be 0.52 for males and 0.13 for females. These figures are not yet corrected for the disproportionate urban coverage of the UCR.

The lifetime arrest figure for males can be checked against intuition very easily. Assume for simplicity that all first arrests occur at age 16. There were about (0.492) (3,480,000) = 1,710,000 16-year-old males in the United States in 1965, and about $\frac{1,710,000}{1.45}$ = 1,180,000 16-year-old males in the population covered by the 1965 UCR arrest data. The 1965 UCR records 4,431,625 male arrests.[13] So with this simple intuitive model, the probability of a male being arrested during his life is about:

$$\frac{\frac{1}{8}(4,431,625)}{1,180,000} \times 100 \text{ percent} \approx 47 \text{ percent}$$

A similar intuitive calculation for females gives 12 percent (using an overall virgin arrest ratio of one-quarter for females).

This approximate calculation also shows that any error in the original data is not compounded into a larger error in the final result. The final result is directly proportional to the virgin arrest ratio, the total number of arrests, and inversely to the population. Thus, a 10-percent error, for example, in any of these data would simply produce a 10-percent error in the final result. These same considerations apply to the more detailed computations for each age group.

The principal reason for the difference in results of the two calculations, 52 and 13 percent versus 47 and 12 percent, is that in 1965 there were fewer persons in each of the age groups beyond age 16, and that the first calculation took into account a significant fraction of the first arrests being distributed over these older age groups. Each of these age groups then produced a contribution with a smaller denominator to the sum. Another reason, somewhat less important numerically, is that the first calculation accounted for the survival probabilities, L_t.

Both of these calculations depend critically upon the somewhat uncertain virgin arrest ratio. The value used here has been based on a rather conservative set of assumptions. Nevertheless, there will always be uncertainty resulting from the problem of incompleteness of arrest records. However, on the basis of the data which was available, it appears safe to conclude that if future arrest rates are as high as those in 1965, then the lifetime arrest probabilities will be at least 40 percent for males and 10 percent for females, and possibly even higher.

Of course, figure J–7 probably overestimates the fraction of the *present* population that has an arrest record (say, by looking at the figures corresponding to the cur-

[13] UCR, p. 115.

FIGURE J-6. 1965 VIRGIN ARREST PROBABILITY BY AGE FOR ALL NONTRAFFIC OFFENSES

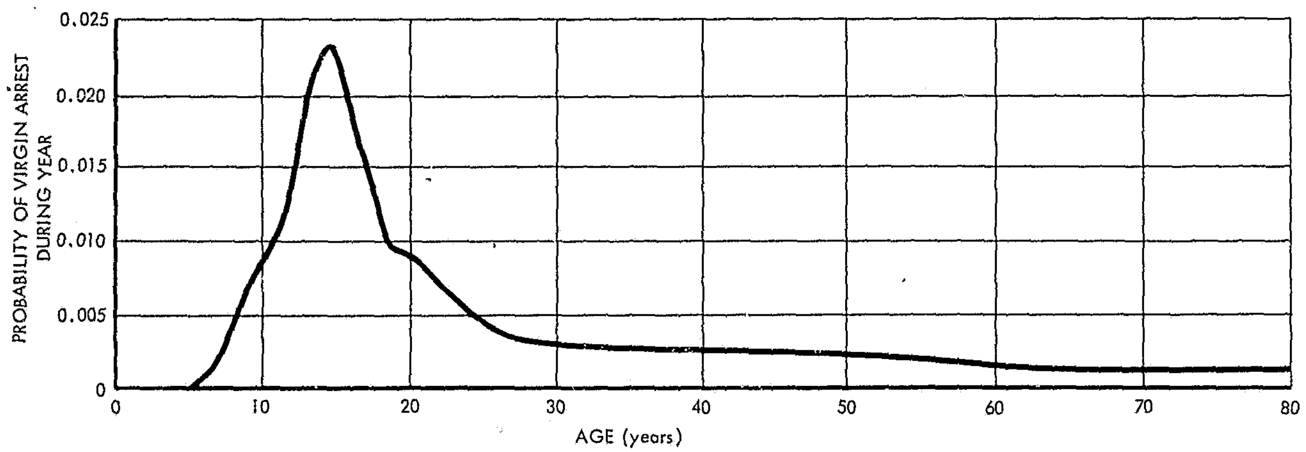
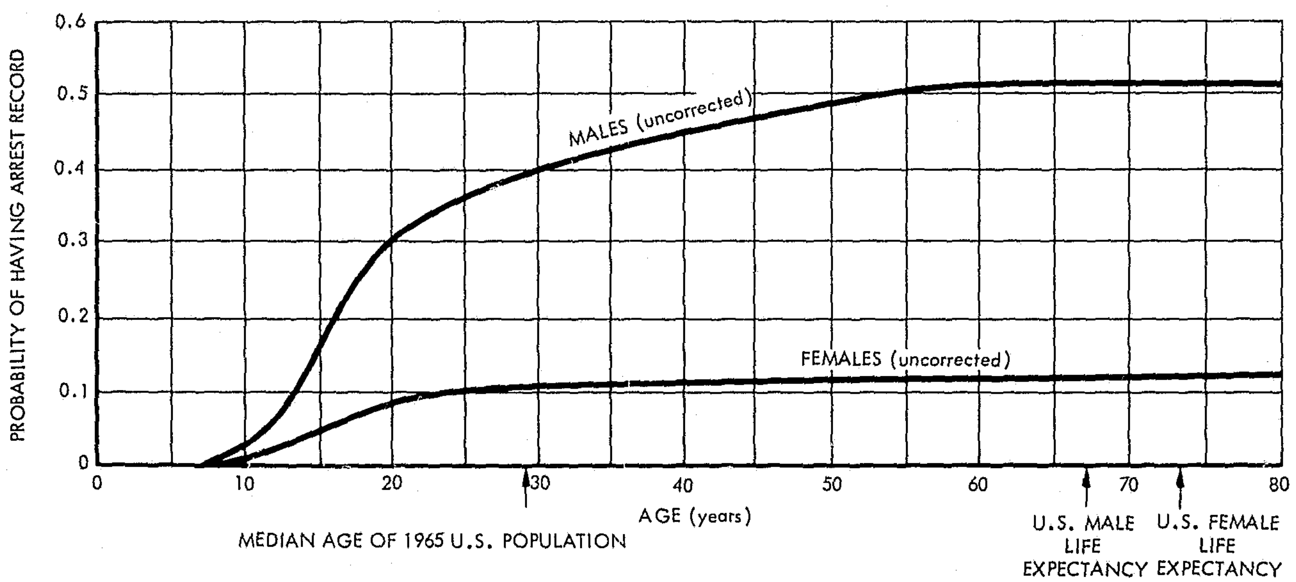


FIGURE J-7. PROBABILITY OF AN INDIVIDUAL 5-YEAR OLD BEING ARRESTED FOR A NONTRAFFIC OFFENSE BY THE TIME HE REACHES GIVEN AGE, ASSUMING FUTURE ARREST PROBABILITIES REMAIN THE SAME AS THOSE IN 1965



rent population median age of 29.5) since the probability of being arrested was lower in the years prior to 1965. A statewide representative sample of 11,329 Minnesota boys and girls (28 percent of all 9th-grade public school children for the 1953–54 school year) showed that by the time they reached 17½ years of age 24.2 percent of the boys and 6.3 percent of the girls had either police or court records for offenses more serious than a minor difficulty with the police, such as a traffic contact.[14] Using 1965 arrest probabilities, figure J–7 shows that, to an age of 17½ years, our analysis gives an estimate of about 25.1 percent for males and 6.5 percent for females.

Statistical research of the County Court of Philadelphia, together with school census figures and U.S. census data, shows that as of 1961 about 21.4 percent of Philadelphia boys and 7.1 percent of the girls were referred to courts before reaching age 18.[15] In Fayette County, Ky., as of 1960 it has been estimated that 20.7 percent of the boys and 5.2 percent of the girls were referred to juvenile court before age 18.[16] Based on data from a representative nationwide sample of juvenile courts, it has been estimated that about 1 in 6 boys and about 1 in 23 girls in the country will be brought into juvenile court for delinquency before 18 years of age.[17]

To distinguish city, suburban, and rural populations on the curves in figure J–8, the appropriate correction factors are:

	City	Suburban	Rural
Males	1.190	0.616	0.431
Females	1.177	.584	.305

For example, the city male correction factor was calculated as follows:

$$\left(\frac{\text{Number UCR city male arrests in 1965}}{\text{Number UCR male arrests in 1965}}\right)\times\left(\frac{\text{1965 UCR population}}{\text{1965 UCR city population}}\right)\times\left(\frac{\text{U.S. male-fraction}}{\text{Urban male-fraction}}\right)$$

$$=\left(\frac{3,928,314}{4,431,625}\right)\left(\frac{134,095,000}{101,652,000}\right)\left(\frac{0.492}{0.484}\right)$$

$$=1.190$$

As an illustrative application, consider a male who was 10 years old in 1965 and who can be expected to live in the city for the next 20 years. The probability that he will be arrested at least once by the time he is 30 is:

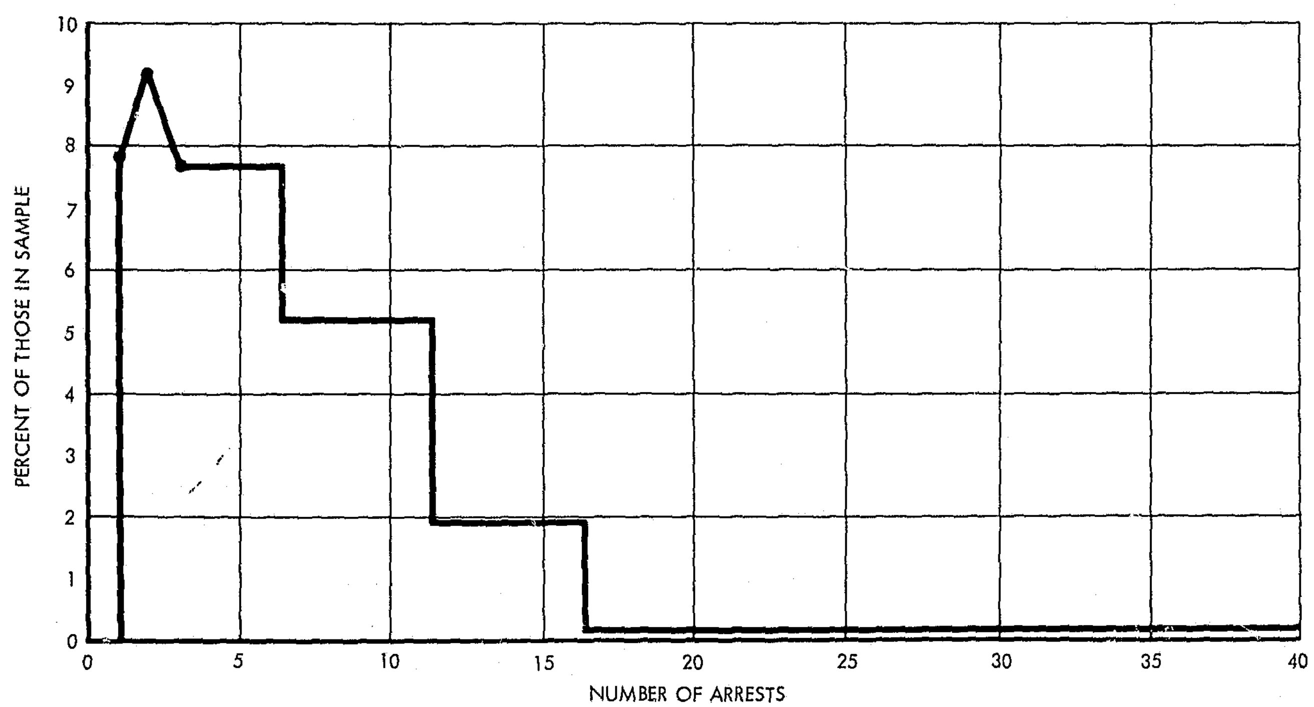
$$1.190\ (0.40-0.03)=0.44$$

Using the above correction factors to provide geographic distinctions for the population, we estimate the lifetime probability of a nontraffic arrest to be:

	Male (percent)	Female (percent)
United States in general	50	12
City	62	15
Suburban	32	7
Rural	22	4

The "United States in general" figures were obtained from the specific figures for "city," "suburban," and "rural" by allocating 67 percent of the U.S. population to city, 12.6 percent to suburban, and 20.4 percent to rural.[18]

FIGURE J-8. ARREST HISTORY FOR SAMPLE OF CONVICTED ADULT FELONS



[14] Hathaway, Stein, Elio Monachesi, and Lawrence A. Young, Journal of Criminal Law, Criminology and Police Science, 50, 433–440 (January–February 1960).

[15] 48th Annual Report of the County Court of Philadelphia, 1961, p. 134; Monahan, Thomas P., "On the Incidence of Delinquency Social Forces," 39, 66–72 (October 1960).

[16] Ball, John C., Alan Ross, and Alice Simpson, "Incidence and Estimated Prevalence of Recording Deliquency in a Metropolitan Area," American Sociological Review, 29, 90–93 (February 1964).

[17] Perlman, I. Richard, "Juvenile Court Statistics," 1964; Children's Bureau Statistical Series, No. 83, HEW, 1965, p. 1.

[18] 1965 UCR, p. 44. Actually, the 67 percent refers to standard metropolitan statistical areas; "suburban," as used in the UCR, includes some counties lying within such areas but excluding the core city. However, the UCR gives insufficient information to improve the allocation.

This then corrects the overall results to roughly account for the disproportionate urban reporting to the UCR.

If we wanted to break these figures down finer, the next logical factor to consider would be economic level. But data correlating arrests to income are not available. However, some racial breakdown data are available, and this does provide limited information on the effects of economic level. Once factors such as sex, income, and residence are considered, any additional differences due to race are small.

To get a racial breakdown, we correct for the number of arrests by race as recorded in the UCR, the population by race as estimated by the Census Bureau, and the basic virgin arrest fraction by race taken as 15 percent for whites and 8 percent for nonwhites. The results are tabulated below:

Males	Percent	Females	Percent
U.S. Males	50	U.S. Females	12
City	62	City	15
White	58	White	14
Nonwhite	[19] >90	Nonwhite	25
Suburban	32	Suburban	7
White	30	White	7
Nonwhite	55	Nonwhite	12
Rural	22	Rural	4
White	21	White	3
Nonwhite	38	Nonwhite	7

[19] The data used was not sufficiently accurate to justify making other than general estimates of percentages exceeding roughly 80 percent. In this case, effects such as differential survival probabilities between males and females and whites and nonwhites, which were not taken into consideration, as well as the basic uncertainties in the virgin arrest ratios can produce distortions with greater absolute magnitudes.

CONVICTIONS

The data problems which limited the previous analysis on arrests was serious, but could be overcome by taking a number of approaches and by trying various data sources. In trying to extend the analysis to include convictions rather than only arrests, the data problems became even more severe, and very crude approximations became necessary. Despite these limitations, that extension is made here, largely to illustrate the approach, to provide a first order-of-magnitude estimate, and to identify the data still needed.

The conviction analysis is based on integration over age of virgin conviction probabilities. Since age-specific conviction probability data is not available, we carry out this integration by summing over the average virgin conviction probabilities for a time-slice of the population. This amounts to assuming that the population-age distribution is flat; i.e., the same number of people falling in each age group, with nobody in age groups past the expected remaining lifetime T beyond the age at which we start our cohort. If the total population is P_{total}, then the number in any age group in this model is $M=P_{total}/T$. The lifetime conviction probability is then:

$$P=\frac{r_cC}{M}=\frac{r_cC}{P_{total}/T}$$

where C is the number of convictions per year and r_c is the fraction of convictions which are of persons never before convicted.

The actual population-age distribution is more dense at the young ages. Thus, since most virgin convictions occur toward the early part of the life expectancy, the flat distribution assumption, which was necessary because of the unavailability of national age-specific conviction data, will result in an overestimate of lifetime conviction probabilities. To estimate the amount of error introduced by the flat distribution assumption, this assumption can be applied to the arrest calculations. This would have resulted in estimates of 64 and 17.5 percent for lifetime arrest probabilities of males and females, respectively, instead of 52 and 13 percent which resulted from the actual distribution. Since most virgin convictions occur within a few years after most virgin arrests, it is reasonable to estimate the actual lifetime conviction results by introducing correction factors of $\frac{52}{64}=0.81$ for males and $\frac{13}{17.5}=0.74$ for females.

The probability of an adult being charged with a part I offense [20] and being convicted (of the charged offense or a lesser offense) in an adult court in 1965 was:[21]

$$\left(\frac{\text{1965 part I city convictions}}{\text{1965 UCR city population}}\right)$$

$$\times\left\{\frac{\dfrac{\text{city population}}{\text{total population}}}{\dfrac{\text{city arrests}}{\text{total arrests}}}\right\}$$

$$\times\left(\frac{\text{1965 U.S. population}}{\text{1965 U.S. population} \geq 18}\right)$$

$$=\left(\frac{120{,}736}{56{,}554{,}000}\right)\left\{\frac{\dfrac{101{,}652{,}000}{134{,}095{,}000}}{\dfrac{4{,}401{,}598}{4{,}955{,}047}}\right\}\left(\frac{194{,}400{,}000}{124{,}099{,}000}\right)$$

$$=0.00285$$

Next we need the fraction of those convicted who do not have a prior conviction record. For a sample of 88 U.S. District Courts in 1964 this was 0.349, being 0.326 for males and 0.609 for females. These numbers would probably be unrepresentative of many UCR-type crimes (e.g., drunkenness which has a very high recidivism rate). Lacking better data, however, we will make our preliminary calculations using these numbers, recognizing that the final results may be in error.

Further, we assume for purposes of making a first estimate that male and female conviction probabilities are the same. Then, assuming conviction probabilities do not change in future years, the probability of an indi-

[20] These offenses are criminal homicide (murder and nonnegligent manslaughter, and manslaughter by negligence), forcible rape, robbery, aggravated assault, burglary—breaking or entering, larceny—theft, and auto theft.

[21] Different tables in the UCR have different population bases. Hence, it has been necessary to include appropriate population terms, since individual ratios must use the population base of the particular table.

vidual who was 18 in 1965 eventually being charged with a part I offense and convicted is:

Males:

$$(0.00285)\left(\begin{array}{c}\text{Fraction of 1965 part I}\\ \text{offense arrests which}\\ \text{were of males}\end{array}\right)$$

$$\left(\frac{\text{Male first conviction fraction}}{\text{Male fraction of population}}\right)$$

$$\times(\text{remaining male life expectancy})$$

$$=(0.00285)(0.866)\left(\frac{0.326}{0.492}\right)(67-17)$$

$$=0.0818$$

Females:

$$(0.00285)\left(\begin{array}{c}\text{Fraction of 1965 part I}\\ \text{offense arrests which}\\ \text{were of females}\end{array}\right)$$

$$\left(\frac{\text{Female first conviction fraction}}{\text{Female fraction of population}}\right)$$

$$\times(\text{remaining female life expectancy})$$

$$=(0.00285)(0.134)\left(\frac{0.609}{0.508}\right)(73-17)$$

$$=0.0256$$

Now, applying the sex-residence correction factors given previously, we can calculate the lifetime probability, by sex and residence, of an adult conviction, which results from being charged with a part I offense:[22]

	Males, percent	Females, percent
City	7.9	2.4
Suburban	4.0	1.2
Rural	2.8	0.6

Table J-2.—Calculation of Convictions per Arrest

	All arrests (percent)	Part I arrests ÷all arrests	Part I 1st arrest fraction ÷all 1st-arrest fraction	Part I arrests (percent)	Convictions on a part I charge (percent)	Convictions per part I arrest
Males:						
City	62	0.158	2	19.6	7.9	0.40
Suburban	32	.201	2	12.9	4.0	0.32
Rural	22	.193	2	8.5	2.8	0.33
Females:						
City	15	.189	2	5.7	2.4	0.39
Suburban	7	.219	2	3.1	1.2	0.36
Rural	4	.130	2	1.0	0.6	0.52

We make the assumption that the part I first-arrest fraction divided by the fraction of all arrests that are first arrests is approximately two. This is based on the data that one-fourth of the 1965 entries in the FBI criminal career file were new entries and one-eighth of the total U.S. arrest in 1965 were first arrests. We now estimate the fraction of convictions per part I arrests.[22] The calculation is tabulated in table J-2.

Next, we assume that the fractions of convictions per arrest for part I arrests are roughly typical of the fractions for all arrests.[23] Then, using these estimates of the fractions of convictions per arrest, we can make the following order-of-magnitude estimates of the lifetime conviction probabilities for all UCR-type charges:

	Arrests (percent)	Convictions per arrest	Corrected lifetime convictions percentage
Males			19
City	62	0.40	25
Suburban	32	.32	10
Rural	22	.33	7
Females			5
City	15	.39	6
Suburban	7	.36	3
Rural	4	.52	2

The reasonableness of these results, which imply that a fraction of $f\approx0.12$ of the population is eventually convicted, can be seen by the following consideration. Let P be the total U.S. population, g be the fraction which is at any point in time under supervision of some sort in the correctional system, and T be the total number of years under correctional supervision during the life of an average individual in the fraction f. Then, since the average lifetime is about 70 years:

$$\frac{70}{T}\,gP=fP$$

From correctional [24] data, $g\approx0.007$.

Therefore:

$$f\approx\frac{0.49}{T}$$

Thus, $f\approx0.12$ implies that $T\approx4$ years. Although insufficient data has been found to permit an independent calculation of T, this does appear to be in the realm of the reasonable.

LIFETIME ARREST HISTORY PROFILES

We will now estimate lifetime arrest history profiles for the U.S. population. First, let us look at the male population.

One estimate of the profile can be obtained by assuming that after the first arrest, subsequent arrests are statistically independent in the sense that their frequency of

[22] Corrected for age distribution by including a factor 0.81 for males and 0.74 for females, as previously discussed.

[23] Since part I charges represent the more serious charges, this is probably a conservative assumption.

[24] See chapter 4. This includes correctional detention, probation, institutionalization of all kinds, and parole and other aftercare.

occurrence is given by the Poisson distribution. Then if p is the probability of being arrested at least once, the probability of being arrested n times is given by pq_{n-1}, where:

$$q_n=\frac{S^n}{n!}\,e^{-S}$$

is the probability of n subsequent arrests given a first arrest, and:

$$S=\frac{1}{r}-1$$

is the average number of subsequent arrests of those arrested at least once.

For $p=0.5$, $r=0.125$, the resulting curve is plotted on figure J–9 (dotted line), where the vertical axis is number of arrests (n) and the horizontal axis is arrest-nonproneness (x) measured in percentile of the population arranged in order of decreasing number of arrests. For example, an individual having arrest-nonproneness $x=30$ percent means that 30 percent of the male population is arrested at least as many times as he is.

Another estimate of the profile can be obtained from District of Columbia Crime Commission data. The percent of the sample of convicted adult felons with a history of a specific number of arrests versus the number of arrests [25] is plotted on figure J–8. Subdividing the $p=50$ percent accordingly, we obtain the dashed curve on figure J–9. Although convicted adult felons may not represent the arrested population generally in terms of number of arrests, this appears to be the best data available. The points on the dashed curve, drawn in step fashion, can be approximated rather closely by a simple exponential function of the form

$$x=50e^{-n/a}$$

where a is the mean number of arrests of those who have been arrested at least once. The fact that a is the mean can be verified in the equation:

$$50a=\int_0^\infty x\,dn$$

Using 1965 UCR data, the area under the curve should be:

$$A=\left(\frac{\text{males arrested per year}}{\text{male population}}\right)(\text{average male lifetime})$$

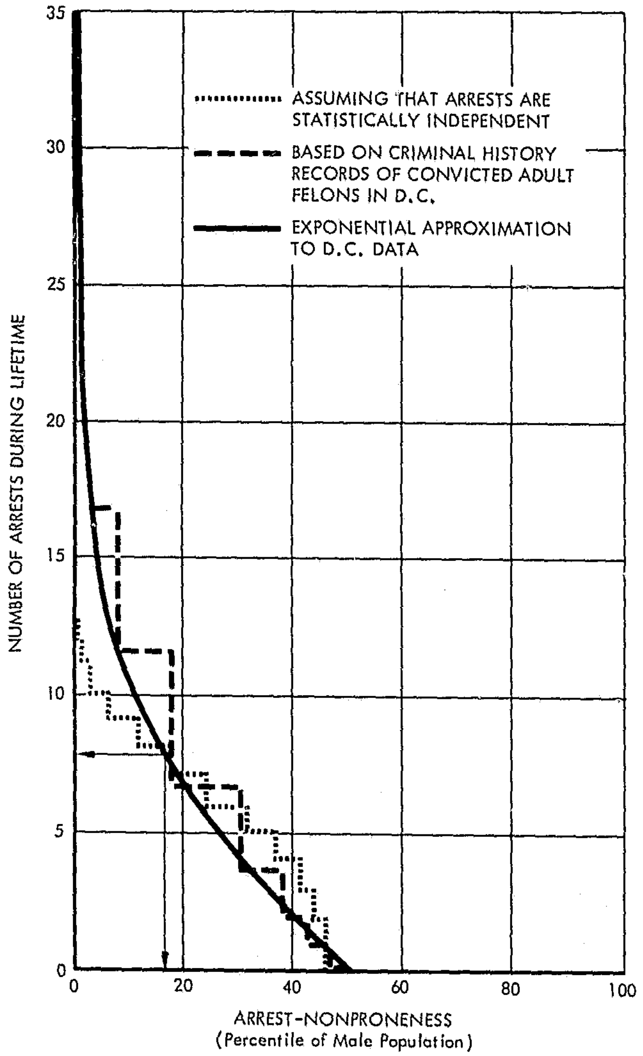
$\times$ age distribution correction factor/geographic correction factor

$\times$100 percent

$$=\frac{(4{,}431{,}625)(67)}{(0.492)(134{,}095{,}000)}\times\frac{0.81}{0.96}\times 100$$

$$=382$$

FIGURE J-9. PROJECTED ARREST HISTORY PROFILE FOR U.S. MALE POPULATION



Using this datum, we can determine a.

$$\int_0^\infty x\,dn=50a=382$$

$$\therefore a\approx 7.6$$

This is consistent with our previous estimate that about one-eighth of all arrests are first arrests.

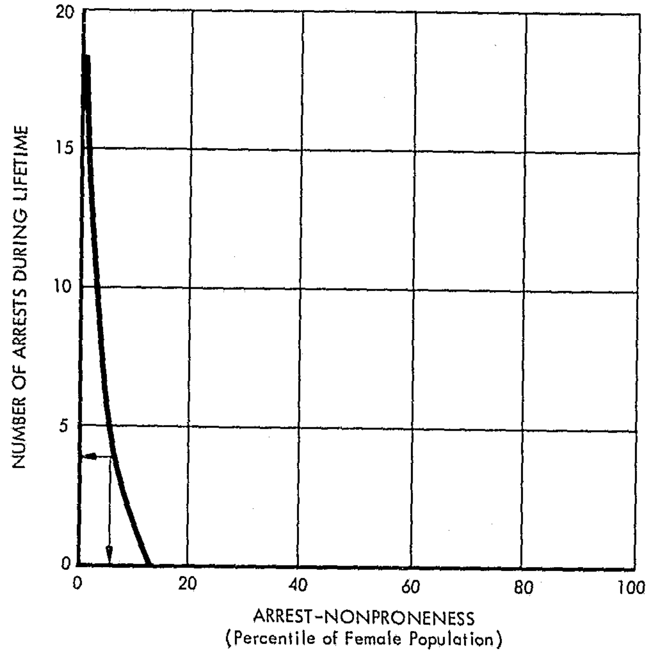
The curve:

$$x=50e^{-n/7.6}$$

is the solid line on figure J–9.

[25] Report to the President on Crime in the District of Columbia, 1966, app., p. 591.

FIGURE J-10. PROJECTED ARREST HISTORY PROFILE FOR U.S. FEMALE POPULATION



Suppose, for example, we define strong repeaters as those who experience more than the average number of arrests (7.6) for nontraffic offenses in their lifetimes. The percentage of the male population who are strong repeaters is then:

$$x_s=50e^{-1}$$

$$\approx 18\text{ percent}$$

From figure J–9, we can also calculate the probabilities p_i, given the individual is arrested at least i times, that he is arrested at least $i+1$ times.

We have already established that $p_0\approx 0.5$. To find p_i for $i\geqq 1$, we set $i=n+1$ and evaluate:

$$p_i=\frac{x(n+1)}{x(n)} \quad \text{(by the definition of } x\text{)}$$

$$=e^{-1/a}$$

Using $a=7.6$:

$$p_i\approx 0.88 \text{ for all } i\geq 1$$

These results show that there is a striking difference between those people who get arrested at least once and those who do not. The strong correlation between the first arrest and subsequent arrests, which shows up in the fact that $p_i \gg p_0$ for $i\geqq 1$, indicates that there is a phenomenon of arrest-proneness. Were there no correlation between arrests, then they would be Poisson distributed over the whole population and not just the arrested population. If so, then we would expect the average number of arrests of those arrested at least once to be only:

$$\frac{-ln(1-p_o)}{p_o}=\frac{-ln(1-0.5)}{0.5}$$

$$\approx 1.36$$

In reality it is about eight, a much larger number. So arrests are not Poisson distributed over the whole population. In fact, there is even a correlation between subsequent arrests, since the distribution over the arrested population is closer to an exponential distribution than to a Poisson distribution, as we have seen.

Repeating this same calculation for females, we have:

$$A'=\frac{(599{,}768)(73)}{(0.508)(134{,}095{,}000)}\times\frac{0.74}{0.96}\times 100$$

$$=49.8$$

$$a'=\frac{49.8}{13.0}$$

$$\approx 3.8$$

If arrests were uncorrelated, one would expect a' to be

$$-\frac{ln(1-0.13)}{0.13}\approx 1.96$$

The resulting curve:

$$x'=13e^{-n'/3.8}$$

is plotted on figure J–10. Using the same definition, the percentage of strong repeaters among the female population is:

$$x_s'=5\text{ percent}$$

LIFETIME CONVICTION HISTORY PROFILES

In the previous section, we estimated lifetime arrest history profiles. We now turn to convictions. For males, the relevant data is: [26]

$$C=(\text{male convictions per male arrest})\,A$$

$$=(0.36)382$$

$$=137$$

$$a''=\frac{137}{19}$$

$$=7.2$$

[26] This says that the average number of convictions during the life of those convicted at least once (including convictions for such things as drunkenness), assuming 1965 conviction rates hold into the future, is expected to be 7.2 for males.

The resulting curve

$$y = 19e^{-N/7.2}$$

is the upper curve on figure J–11. The corresponding curve

$$y' = 5e^{-N'/4.1}$$

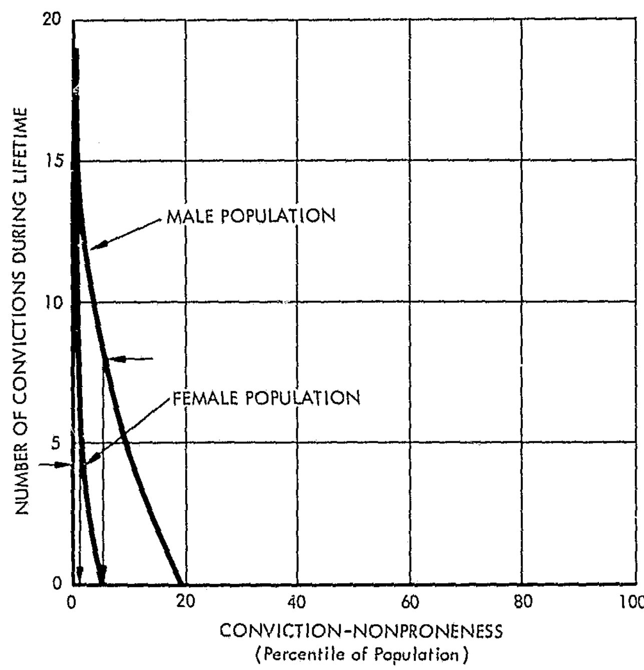
for females is the lower curve on Figure J–11.

Using a definition of "strong repeater" for convictions similar to that for arrests, we obtain

$$y_s = 7 \text{ percent}$$
$$y'_s = 2 \text{ percent}$$

as the percentage of the male and female populations, respectively, who are strong repeaters in convictions (over 7.2 lifetime convictions for males and 4.1 for females).

FIGURE J-11. PROJECTED CONVICTION HISTORY PROFILE FOR U.S. POPULATION



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