Allocations of Resources in the Chicago Police Department

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Report of the
OPERATIONS RESEARCH TASK FORCE
Of the
CHICAGO POLICE DEPARTMENT

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U.S. DEPARTMENT OF JUSTICE

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FORWORD

The work reported herein is potentially of great significance in the effort to improve the quality of law enforcement in the United States. This project shows how scientific methods can be used to define objectives for police agencies, establish criteria by which progress towards these objectives can be measured, and suggest tactical or procedural methods for efficiently using police resources to achieve these objectives.

This report contains much technical material unfamiliar to law enforcement personnel which is included in any effort to help management science consultants assist police with many of their problems. Members of the law enforcement community hopefully will take the opportunity to use the kinds of assistance presented in this study and otherwise available through a variety of Federal programs.

The report is printed with the hope that those concerned will profit from a study of these developments. While the application of operations research and systems analysis will not be the answer to all the problems of law enforcement, they do appear to offer more hope and progress than depending on past experience or intuition alone.

MARTIN B. DANZIGER
Assistant Administrator
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PREFACE

The list of individual contributors to the mission of the Operations Research Task Force is a long one. At the risk of omitting credit to some whose contribution was significant, particular gratitude is expressed to Dr. Robert Emrich and Dr. Jay Merrill of the National Institute of Law Enforcement and Criminal Justice. Dr. Sigmund L. Walesczack, Dr. George A. Contos, and Dr. John Y. Barry also gave generously of their time to review the technical work in progress. Dr. Gustav J. Rath, Northwestern University, and Dr. Thomas A. Caywood participated as individuals in many discussions of the project's problems and approaches.

Special thanks go to the Communications Center personnel, Chicago Police Department, who willingly bore many additional data gathering and procedural burdens; to personnel in the Data Systems Division for their special computer tapes and keypunch data; and to the District Commander and the personnel of the 14th District for their participation in a full-scale administrative experiment during the summer of 1969.

This version of the Final Report of the Operations Research Task Force is the result of editing and tightening carried out by the Project Director over a period of approximately one year at no cost to the U.S. Department of Justice or the City of Chicago. This remains a technical report. It is intended for those who seek to participate in the process of improving Law Enforcement in the United States through application of the methods of operations research system analysis, and the computer sciences.

There is much in the report that can be used by the Police Administrator. Detailed techniques, however, are drawn from disciplines that Law Enforcement personnel are not generally familiar with. They do not need to be. They must, however, recognize that staff functions are just as important in Law Enforcement as they are in military affairs.

I acknowledge the contributions made by the civilian and police staff of the Operations Research Task Force during performance of this project but take responsibility for the content of this version.

Albert M. Bottoms
Monument Beach, Massachusetts
February 1971

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BACKGROUND AND RECOMMENDATIONS

A major conclusion of the Presidential Commission on Crime and Law Enforcement, reporting in the Spring of 1967, was that major law enforcement agencies should make use of the techniques of operations research and systems analysis. These techniques should improve the Police administrator's choice in resource allocation, manpower utilization, and equipment evaluation and selection. Under the leadership of O. W. Wilson, the former superintendent of the Chicago Police Department, the department applied for an operations research project grant under provisions of the Law Enforcement Assistance Act of 1965. The grant was awarded in August, 1967, and actual work commenced in February of 1968 when a qualified project director was obtained.

Chicago's request was a natural outgrowth of the report of the Crime Commission. Additional justifications for a major Law Enforcement Assistance Administration study here included the existence of the most modern Police command and control system in the United States, a large computerized data base, and the dynamic reputation of the Chicago Police Department. In general, these conditions are necessary for the success of any scientifically-oriented project in the military service, in business, or in a law enforcement agency.

Impetus was given the project by recognition within the Chicago Police Department of a need to review uses of manpower in the Patrol Division (motorized beat structure) in view of rising crime rates and increasing workloads imposed upon a force which might not be able to expand to meet all demands placed upon it.

Police administrators of all law enforcement agencies will recognize the universal nature of this problem. Hence, the results obtained by the project and the further approaches suggested in the report can prove useful to law enforcement agencies throughout the United States.

The major objectives of the project were to:

1. Demonstrate the applicability of operations research and systems analysis techniques to problems of resource allocation in a major police department.

2. Prove the feasibility of conducting operations research studies with an "in-house" scientific group as opposed to the practice of using outside civilian consultants.

3. Familiarize, indoctrinate, and train police officials from Chicago and other cities in approaches, capabilities, and limitations of operations research.

RELEVANCE TO POLICE

As shown in this report, the resource allocation project in the Chicago Police Department demonstrated the relevance and potential value of a number of specific approaches. The project has assisted in the conduct of some field experiments and tests. Time and limited resources did not permit implementation, on a continuing basis, of any of the recommendations even though some approaches offered great promise. The project was a staff operation, reporting to the Superintendent of Police through the Director of the Planning Division. Project activities were coordinated with operating units through the Operations Research Advisory Board. The project report is thus a staff study that can be regarded as a preliminary design study or an exploratory study. This is an important point.

A study of an operational organization itself cannot result in complete reorientation and reorganization without detailed staff activity, training, personnel changes and organizational changes; however, the study is a prerequisite to achievement of desired results. The demonstration of potential approaches presented herein is credible and possible within existing internal and external constraints which affect a police department. It is believed that evolutionary processes in reorientation and reorganization of a police department, necessary for testing of innovative approaches and techniques, are inevitable.

Operations Research Task Force (ORTF)

The Operations Research Task Force was established in February 1968. It consisted of four civilian analysts and seven police officers. A unique and most valuable feature of the ORTF was the joint police-civilian scientist organizational arrangement within which individuals worked singly or in small groups without regard to police or civilian status. This enabled development of relevant analytical approaches by combining police experience with the technical capabilities of civilian scientists.

The project director was a civilian responsible for the program in general and for the technical content of the work. The deputy project director, a captain in the Chicago Police Department responsible for official liaison with all units, provided the police link in the chain of command for officers assigned to the ORTF. This approach was patterned directly from a joint military-civilian study group in the Department of Defense, and it proved that it would be a viable method whether the civilian component were "in-house" or provided under a contractual arrangement.

Analysis plan

The approach of the ORTF to the problem of resource allocation in the Chicago Police Department was to:

a. understand Chicago as an environment in which law enforcement activities take place.

b. examine overall police resource allocation in the light of community criteria.

c. analyze the functional aspects of law enforcement response to calls for police service and aggressive preventive patrol.

d. conduct field experiments, when possible.

Within the Chicago Police Department, the training objective was accomplished through oral and written reports, individual discussion, and by the use of an apprenticeship method whereby officers were assigned to the ORTF.

Operations Research Advisory Board

For administrative purposes, the ORTF was placed in the Planning Division in the Office of the Superintendent of Police. The Director of the ORTF reported directly to the Director of Planning. Communication of project results was to an OR Advisory board. This board coordinated the research effort and assured continuing relevance of the various tasks. The OR Advisory Board consisted of the deputy superintendents for Field Services, Staff Services, and Inspectional Services plus the directors of Personnel, Data Systems, Finance, Records and Communications and the executive assistant to the Superintendent. The Director of Planning acted as chairman of the OR Advisory Board.

The OR Advisory Board proved to be an effective body insofar as providing means for communication. Where necessary and appropriate, the OR Advisory Board authorized direct liaison between the ORTF and other organizational units such as the Patrol Division, the Detective Division, and subordinate field units.

Role of consultants

It is essential that a pioneering effort such as the Chicago Police Department Resource Allocation Project obtain specialized outside help and objective criticism. It is even more important that adequate computational facilities be available and accessible to analysts. These needs were not fully appreciated in the application for OLEA Grant 195. Grant adjustments permitted the ORTF to obtain some consultative services and use of the major computer facility at Northwestern University. Professional technical review was obtained through a panel whose members served, without compensation, on an informal but continuous basis. Such a review is essential when scientists are under time pressure to get results while extending known techniques into new fields. Panel members included distinguished operations research scientists from government, industry, and universities.

Principal approaches and efforts of the ORTF are detailed in Chapter 1, following the major conclusions and recommendations of the study. This chapter will aid the police administrator or public official who needs an overview of the resource allocation problem. Few executives need or want to become involved in the technical and analytical details or possess the formal training necessary to follow all the technicalities. Other chapters contain more detail, but they are essentially non-technical. Operations analysts will find a wealth of specific analytical material, supporting the interpretative chapters, in the appendices.

RECOMMENDATIONS

The principal conclusion of this demonstration project is that resource allocation problems of law enforcement agencies are amenable to operations research and system analysis methods. Units similar to the Operations Research Task Force of the Chicago

Police Department should be established and actively supported within every major law enforcement agency.

Unless there is a major scientific unit organic to a municipal government to which a civilian professional staff of police operations research scientists could be assigned, an Operations Research Task Force consisting of sworn police personnel should be established within the planning unit of a police department. This group should be supported by long-term contractual relationships with universities, non-profit, and profit-making scientific organizations. It is emphasized that police departments will require professional guidance in the selection of contractors or scientific personnel.

Management Information System Needed

The most significant recommendation to the Chicago Police Department to improve efficiency of the resource allocation capability is to develop and implement a computer-assisted police management information system. The evolutionary characteristics of such a system suggests a time-phase plan of implementation and development so as to produce early results.

The current high level of emergency police service to the citizens of Chicago should be maintained. However, it is vital that a method be found to increase availability and decrease workload of district patrol units. One alternative is to increase the number of patrol units. The critical consideration then becomes saturation of the Communications Center capability. Improved supervision by field personnel to decrease service time could delay reaching the communications saturation level, but if the trend of recent years continues, this effort alone will not be sufficient. Adoption of a policy which permits stacking, increased screening, and deferral of police service to calls of non-emergency nature appears to offer the most promise. Adverse public reaction to any inconvenience in non-emergency situations can be offset by adherence to the current high level of response to emergency calls.

Shift to Resource Analysis Budget

Planning can be facilitated through the use of a resource analysis budget which shows how financial resources are applied to the major goals of the Chicago Police Department. The performance budget of the City of Chicago can be readily transformed into a resource analysis budget.

The Planning Division can prepare a resource analysis budget annually and should prepare recommendations to command staff which facilitate future financial decisions. The resource analysis budget can be utilized to establish resource allocation priorities.

To Improve Capabilities

The Operations Resource Task Force submits several recommendations to improve the capabilities of the Chicago Police Department. Some recommendations are within the capability of the Department while others will require the assistance of outside agencies.

It is recommended that the Department:

A. *revise the current policy relating to assignment of patrol units to non-emergency calls for service to permit stacking, increased screening, and deferral.*

B. *implement the use of analytical methods to allocate Patrol Division resources between a response force and a preventive force.* Each district will present unique problems of implementation. Emphasis must be placed on the development of mission assignments for the preventive force units so as to maximize the potential benefits of the split-force concept.

C. *adopt the use of service time distribution data as a measure to increase effective field supervision which improves availability of patrol units.* The car-outage report should be an exception report. Service time norms must be consistent with professional standards of police service.

D. *establish procedures for the use of crime incidence maps to assist allocation of resources to preventive patrol.* The lack of correlation between the clustering of criminal events and mission assignments to patrol units identifies this problem area. Plotting to the maps can be accomplished by hand until computer assistance is available.

E. *contract for computer-graphics presentations of crimes by type and time of day as an interim procedure until in-house capabilities are developed.* Analytical techniques for allocation of preventive patrol units have been developed by the Operations Research Task Force and are programmed for the computer at Northwestern University.

F. *keypunch information from administrative cards into the Department data base.* Revision of computer-produced reports of Department activity which includes this additional information will greatly assist analysis of the commitment of police resources. Currently, over 70% of the total calls for service are categorized as "Other".

G. *continue the joint scientist-law enforcement official effort in solving operational and resource allocation problems.* The application of advanced technology to problem areas and the resultant alternative solutions can be documented to provide powerful support to the decision-making process.

H. *utilize the resource analysis budget as a tool in planning police effort to attain Department objectives.*

I. *strengthen the Chicago Police Department capability for planning and evaluation of resource allocation policies by providing outside professional, technical and analytical support to the Planning Division.*

Priorities For The Future

The following list of suggested future projects is in an order of priority as seen by the Director, Operations Research Task Force. Projects followed by the letter "P" are those that can be undertaken by the Department without outside technical guidance. Those followed by the letter "S" require execution by scientific personnel based upon Department guidance. Projects in which efforts of both the Department and scientific personnel are required are followed by the letters "S–P." Suggested for the future:

Conduct a study to determine the requirements of a Management Information System. (S)

Conduct a study to determine alternatives to the current laborious keypunching system. (S)

Conduct cost-benefit analyses of the following units of the Department to support resource allocations decisions: Bureau of Staff Services, Detective Division, Intelligence Division, Traffic Division and Vice Control Division. (S)

Expand experiments of the split-force concept to additional districts, progressing to those with more complex problems of crime control. (P)

Continue the study of specific crime problems in various districts and areas. (P)

Conduct neighborhood and district surveys to ascertain weights associated with serious crimes by citizens; this could be carried out through the Community Workshop Program. (P—See Chapter 5)

Develop methods to allocate manpower to preventive patrol assignment; concurrently, preventive patrol tactics must be designed for specific crime problems such as auto theft, burglary, robbery, and patrol of high rises. (S–P)

Develop and test Coordinated Response tactics. (S–P)

Test the validity of the overall resource allocation method on the dual criteria of providing the desired level of emergency service, and minimizing crime on a city-wide basis by preventive patrol. (S–P)

Develop a capital improvement plan with emphasis on the Communications Center, personal communications equipment, motorized unit communications equipment, and advanced technology which can assist intelligence, surveillance, and patrol activities. (C)

Develop and evaluate contingency plans, procedures and requirements for specialized equipment to contain civil disorders and man-made or natural disasters. An example of a man-made disaster would be a situation such as when a heavily armed man goes berserk. (S–P)

Review current emergency mobilization procedures for modification *in those districts employing the split-force allocation technique.* Units assigned to preventive patrol can be readily mobilized and employed without disruption to normal police service. (P)

Encourage and stimulate university-based research into basic methodologies which apply to the allocation of resources of law enforcement agencies (S)

CHAPTER 1

SYSTEMS ANALYSIS APPLIED TO LAW ENFORCEMENT*

The problem of resource allocation for a police system is similar to that of many other public systems, namely: (1) A lack of agreement regarding the objectives of the system, and their relative importance; (2) A lack of knowledge of alternative means for accomplishing goals, either within or outside the system; (3) A lack of agreement defining the criteria of performance; and (4) A lack of knowledge of transfer functions which would enable the prediction of output from any given set of inputs.

The police system has to be studied as a distinct system within the social structure of society. Optimizing easily quantifiable relationships is likely to obscure the important qualitative aspects.

"The legitimate point (can be made) that police systems can be understood only as institutions in interaction with the rest of the social structure."[1]

IDENTIFICATION OF OBJECTIVES

The Police System objectives are related to law enforcement, order maintenance and public service. Though everyone might agree as to the desirability of the first objective, there is disagreement on what to enforce and how.[2]

"No policeman enforces all the laws of a community. If he did, we would all be in jail before the end of the first day. The laws which are selected for enforcement are those which the power structure of the community wants enforced."[3]

The second objective, order maintenance, designates the police system as a buffer for the social system. This is bound to involve conflict situations in which there is no consensus as to what constitutes order and the propriety of the methods of enforcement employed. The function of public service is much less controversial, but constitutes a large drain on police resources. Often these services could be more efficiently performed by other public or private organizations.

Even if an objective such as crime prevention has been agreed upon, it is important to know the alternative methods which can accomplish the objective. Often the most important aspect of improving a system is the generation of good alternatives. In addition, each null alternative has to be investigated. Instead of devoting additional resources to a police system, they might produce better results if allocated to the courts or correctional agencies, or if used for social work or community building. Thus, it is necessary to consider alternatives outside the police system proper.

Criteria of performance represent the means by which a system is to be evaluated. They should provide a way of measuring how well objectives are being accomplished. For example, is an average response time to a call for service a good criterion; is the number of traffic citations issued by each officer a good indicator of traffic management?

Lastly, there is a lack of quantitative descriptions of the police system. This holds true for descriptions of the system and its environment as well as transfer functions for different activities (a transfer function relates inputs to outputs for a given activity). An input–output guide should permit an indication of, for example, the number of policemen needed to control a mob of 200 people or how many police cars must be in service to achieve a certain response time to high priority calls and how response time relates to the probability of arrest.

Answers are sought for the questions posed earlier, and this work has three objectives:

1. To define the Police System (its objectives, its interfaces with other systems, and measures of effectiveness).
2. To develop a new structure for allocating costs (an accounting system). This structure should facilitate the development of production models and the evaluation of benefits.

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3. To develop production models for the Response Force in order to evaluate alternatives.

Meeting the first objective is partly solved by the presentation of a conceptual model of the Police System.

The second objective is achieved through the Resource Analysis Budget discussed in Chapter 2.

The third objective is met by the development of simulation models described in Chapter 4.

The discussion proceeds from the meta-system level down to models of specific activities. First the Police System, its objectives and criteria are defined. Secondly, to make the resource allocation problem manageable, a structure is developed for cost-benefit analysis. This structure is called a Resource Analysis Budget and necessitates a whole new accounting system. The present allocation of resources are calculated for this new accounting structure. Lastly, production models are used to determine efficient combinations of resources.

USING SYSTEMS ANALYSIS

The systems approach is a rational framework for complex problem solving emphasizing hierarchies of systems and their interrelationships. Most often the problem is ill-structured and the objectives are unknown or undefined.

"The systems approach is one in which we fit an individual action or relationship into the bigger system of which it is part, and one in which there ix a tendency to represent the system in a formal model."[4]

The systems approach is the methodology used to develop a conceptual model of the police system. The model specifies the objectives and the outputs of the police system and consequently permits determination of output categories (programs) for the Resource Analysis Budget. The systems approach offers a tool for structuring the analysis, and consequently some protection against erroneous suboptimizations.

The Police System as well as the Criminal Justice System is a largely uncharted area. Suboptimizations are ever present hazards; in fact, the optimization of Police System performance is itself a suboptimization.

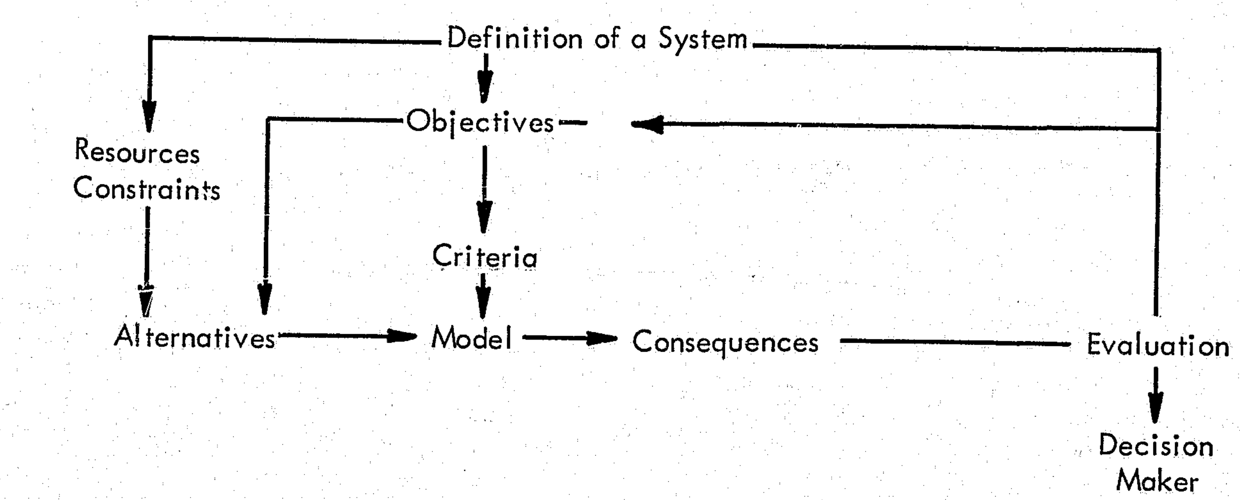
"A system may be defined as a set of objects, either fixed or mobile, and all relationships that may exist between the objects. All systems are composed of subsystems and are members of a higher system."[5]

For example, the Police System is in part a member of the Criminal Justice System which is part of the Social System within which our society exists. The Police System, in turn, is a set of sub-systems.

For resource allocation analysis, these sub-systems are a set of mission oriented (output oriented) subsystems. These sub-systems are usually called programs. The cost structure of the system, with respect

Figure 1-1 : Systems Analysis Paradigm

(Adapted from Kenneth Heathington and Gustave Rath, " The Systems Approach in Traffic Engineering, " op. cit.)



to the given programs, is called The Program Budget. The analyst tries to select a set of sub-systems which:

1. Are consonant with the plan of the decision maker;
2. Have operational objectives and measures of performance;
3. Are as independent as possible;
4. Facilitate cost-effectiveness analysis.

An environment may be defined as a set of objects outside the system. It is the aggregate of external conditions which affect the system.

The systems approach can be succinctly exhibited in a paradigm. The following steps should be considered in drawing a systems analysis. (See figure 1-1)[6]

1. Define the desired goals.
2. Develop alternative means for realizing the goals.
3. Develop resource requirements for each alternative.
4. Design a model for determining outputs of each alternative.
5. Establish measurements of effectiveness for evaluating alternatives.

After a system and its environment have been specified, the analyst should consider the objectives of the system and the resources and general constraints which are present. Resources are the total available material which can be allocated. Constraints are limitations imposed on the system.

The objectives express what the system is trying to achieve and to what end resources should be applied. An objective should be defined in such a way that an operational, quantitative measure of performance is possible. It is of little use to have an objective which cannot be quantified.

Equally important are measures of performance. They permit evaluation of how well the objective is being achieved.

ROLE OF ALTERNATIVES

Alternatives offer different means of using resources to achieve objectives. Developing alternatives represents one of the more creative and crucial steps in the systems analysis process. It is here that the analyst seeks to define new alternatives that can provide increased effectiveness over previously considered alternatives.

Once alternatives have been specified, the cost of resources for each alternative has to be determined. This involves considerations of risk, time and different types of costs. To arrive at the benefits of an alternative, a model is necessary. The model determines the output to be derived from a given amount of resources.

Lastly, the cost and benefit of each alternative has to be evaluated to select the optimal alternative. The criterion function relates costs and benefits to system objectives and provides the basis for selection.

"It is my experience that the hardest problems for the systems analyst are not those of analytic techniques . . . . What distinguishes the useful and productive analyst is his ability to formulate (or design) the problem: to choose the appropriate objectives; to define the relevant, important environments or situations in which to test the alternatives, to judge the reliability of his cost and other data, and finally, and not least, his ingenuity in inventing new systems or alternatives to evaluate."[7]

This point cannot be emphasized enough.[8] The great danger in systems analysis lies in not spending enough effort in defining what the system under study should be, and instead seeking to optimize the effectiveness of a given system. The big payoffs are likely to come from a construction of new world views of problems, rather than optimizing current structures.

This point is illustrated in Figure 1-1 by the arrows drawn from the evaluation phase to the objectives and the alternatives.

AN ART IN INFANCY

The current state of the art, with respect to police resource allocation optimization, is in its infancy. Most research into the Criminal Justice System has dealt exclusively with the social dimensions. Analytical contributions have appeared only during the last five years.

A systems analysis approach was used by the President's Commission on Crime and Law Enforcement to define the scope of the Criminal Justice System problem possible research approaches and technology that could be applied.

"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."[9]

Blumstein and Larson recently published an article which looks at the flow of people through the Criminal

Justice System.[10] It is not a systems analysis as they do not discuss objectives or measures of effectiveness, but rather a descriptive model of the flows. This step is important, however, as it provides a quantitative description of a portion of the real world.

DESCRIBING A POLICE SYSTEM

From a general point of view, a police system is a service organization. Its clientele are people who have broken the law as well as people in need of help. It is a twenty-four hour, city-wide, dual purpose service force.

The police system is not part of the market mechanism. Its output is not a good sold in the market in competition with other enterprises; it is a public service good. The community devotes a certain amount of resources to the system and expects an output, which never is too well defined. Even if the inputs and the outputs of the system were given, the internal process of a police system is difficult to optimize. Very little is known about the transformation of inputs into outputs (the transfer functions). Consequently, tradeoffs between different methods of controlling crime (for example, using more of fewer detectives or using one-man or two-man patrol units) are not known. This is a serious drawback in trying to allocate resources and develop a departmental budget.

The metropolitan police force is usually a paramilitary system. It is characterized by strong internal controls and centralized decision making. Its organizational goals, as pointed out in the Field Study of San Diego,[11] are primarily oriented towards the crime-fighting function.

The Police System does provide two separate services: Crime control and public service. The former is the main focus of activity as will be shown in the Program Budget. This crime control function is part of the efforts of the Criminal Justice System; the public service function is part of the City Government.

The Police System is a set of sub-systems which are part of higher order systems. (See Figure 1-2) The Police System is a member of the Criminal Justice System (CJS). Its function is preventing criminal events and, failing this, to identify and apprehend the offender. There are other members of the law enforcement agencies in addition to metropolitan police departments; these include federal, state, county and special police, such as Burns, Brinks, etc.

The Police System is also part of the City Government. Its public service mission is a function of the twenty-four hour, city-wide availability of the police force. Part of this function could be carried out by people with no police training. This function includes actions such as animal rescue, locating missing persons, and ambulance service, all of which could be performed by other city agencies or private groups.

The Police Department has another objective, Community Support. The generation process of individuals who may choose a criminal career is deeply rooted in social, psychological and economic variables over which society has some control. Crime is the responsibility of society, and its control cannot be delegated solely to a Police Department. The Police Department responsibility is to deter and apprehend offenders. The Criminal Justice System can effect

Figure 1-2 : Systems Analysis of the Criminal Justice System

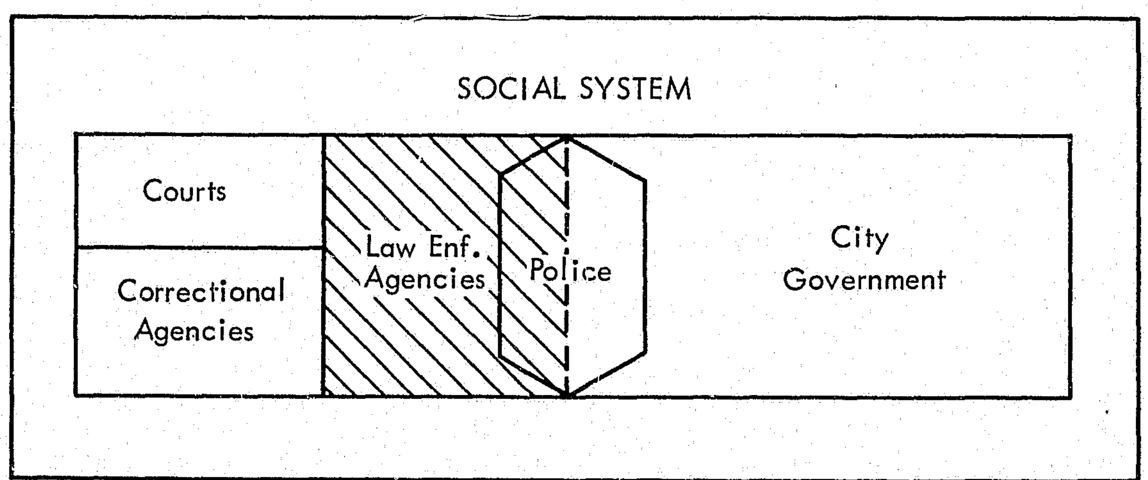
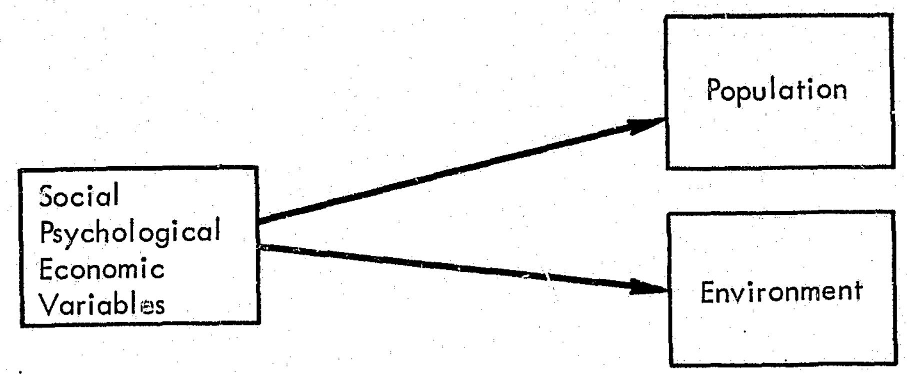


Figure 1-3 : Conceptual Model of the Forcing Function



deterrence, but this is effective only to the extent that society (or the social group to which the potential offender belongs) disapproves of criminal acts.

Community support implies the willingness of the community to fight crime, both by giving support, help, and resources to the Police Department, and by creating means to affect the crime generation process. Instead of actively seeking community support, police departments have often, in their desire to be professional, tended to become systems isolated from the community. This has had some detrimental effect on police effectiveness.

The investigation of the crime control problem will proceed by first analyzing the Criminal Justice System and then, in more detail, the Police System. This will permit the specification of objectives for the Police System.

Criminal Justice System

To help specify the Police System, which is the focal point of the analysis, it is necessary to consider the higher order system. The Criminal Justice System (CJS) has been charged by society to regulate and control certain classes of behavior. These classes of behavior are determined by the legislative branch of government and interpreted by the courts.

The sub-systems of the CJS: The Police, the Courts, and the Correctional Agencies. The police identify misconduct and apprehend the offenders. The courts determine the facts of the case and rule on its disposition. Correctional Agencies administer prisons and supervise the parole system.

How does the CJS affect the generative process of criminal events? The structure of the crime control function is exhibited by a conceptual model. It displays the pertinent sub-systems, decision points and mechanisms for change. It permits an analysis of how the CJS can affect the potential criminal's decision making and how the impact of crime can result in community response.

The model postulates that the forcing function of the crime generation process is a function of social-psychological-economic variable. (see Fig. 1-3)

These variables affect the individual's utility function and consequently affect his propensity towards a criminal career. They also affect the distribution of opportunity by altering the generating mechanism. A discussion of the specific mechanisms is outside the scope of this paper.

Welfare programs provide family assistance which gives children a better start, thus reducing the likelihood of their pursuing a criminal career. Job training programs and increased employment opportunities will provide an alternative to crime for an income. For example, people might demand stricter legislation (i.e., cars must have theft proof locks) or elect voluntarily to lock their cars. In either case, the underlying mechanism generating opportunities has been altered.

Two factors are necessary to create a criminal event. There has to be an individual or group of individuals and a specific set of opportunities. A specific opportunity is defined as a factor of:

1. Type of opportunity (theft, robbery, etc. This leaves open the question of the appropriate classification);
2. Gain (usually in dollars);
3. Availability (this dimension measures the probable degree of difficulty of execution associated with the specific opportunity. This permits differentiation between a car that is locked and unlocked, located in the street or in an underground garage);
4. Location (in space);

5. Time (interval of time when opportunity exists).

For a given type of opportunity, distributions can be generated with respect to location and time. The set of all opportunities is called Environment.

The population considered in the model is the total population of the community. It is a set of individuals characterized for our purposes by the following attributes:

1. The individual's perception of the environment. The model chooses to maintain an actual environment and vary the individual's knowledge of the actual opportunities. The value of this attribute would fall between 0 and 1. That is to say he has incomplete knowledge.

2. The individual's knowledge of deterrence. Deterrence is the expected value of negative benefits that the Criminal Justice System contributes to a given type of opportunity. It is a function of the probability of arrest for a given type of opportunity based on past performance by the police system, the chance of being sentenced, and the length of the consequently jailterm and amount of fine. Again the value would fall between 0 and 1. (These benefits would be pure number to which a utility transformation would be applied).

3. The individual's utility function. The coefficients of this function are determined by past social-psychological-economic effects. The utility function concept will permit an explanation of how past states of the individual will influence his present decision-making. If an offender committed a successful crime (i.e. large monetary reward, not apprehended) one day, he is not likely to attempt another crime the next day. His attitude towards the risk or estimation of his own abilities may have changed as a result of his success. The utility concept also permits analysis of "crimes of passion." The individual puts a low estimation on negative benefits or the positive benefits are very large. That is, the utility function encompasses, among other things, past experience, needs and behavior towards risk.

The decision making process resulting in a criminal event can be viewed as a two-step decision process. This allows distinguishing between inputs, which are a function of the past performance of the CJS, and inputs at the moment of execution.

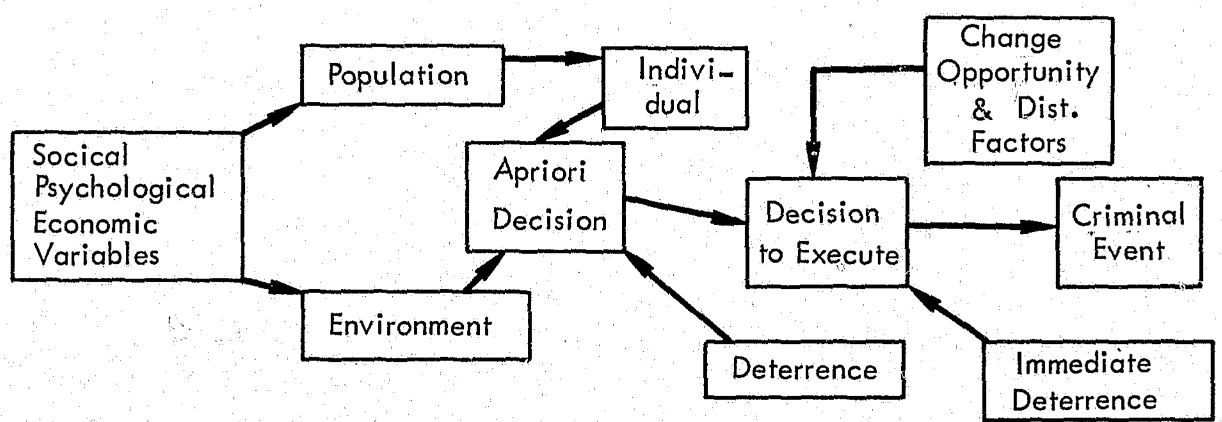
First, the individual is permitted to contemplate the opportunities known to him and make an *apriori* decision to actually commit a specific crime. The relevant input from the CJS deterrence, as defined above, of which the individual has varying degrees of knowledge. Knowing the individual's utility function, the opportunity having the greatest utility can be determined and a "go-no go" decision made.

The second decision point is present immediately prior to the execution of the planned criminal event. The potential offender evaluates the actual circumstances of the opportunity and makes a go-no go decision.

The first stage was an *apriori* decision based on the probable circumstances surrounding the event. The second state becomes the actual sample reflecting: (1) the juncture of the probable circumstances, and (2) action taken either by private groups, (persons) altering the generation of opportunity distributions and or their factors, or police actions affecting deterrence or opportunity distributions. For example, a person might decide to break his habit of not locking his car, or the police department may employ a new tactic against CTA bus robberies.

For many events, commonly called "crimes of opportunity," the time interval between the decision points is very small. However the interval could be measured in days. Figure 1-4 summarizes this discussion in pictorial fashion. It has been said that there is a formula for crime: "Desire plus opportunity equal crime."[12]

Figure 1-4 : Conceptual Model of the Decision Phase



Criminal Justice System Response

What is the CJS reaction to the criminal event and how can it affect the crime generation process?

The Police sub-system responds to the criminal event seeking to identify and apprehend the offender. Police strategy and tactics can influence the decision to execute.

The generation process of crime is affected by deterrence. Deterrence was defined as the expected value of negative benefits which are a function of the risk of arrest, chance of sentencing, length of jailterm, and fines for different classes of criminal events.

The Courts and Correctional Agencies may either emphasize deterrence or rehabilitation. Rehabilitation is the effect the CJS has on the individual as he is processed through the CJS, resulting in a change in his utility function. The Police contribute through special handling of juvenile offenders, the courts by the sentence they provide, and the correctional agencies by programs which seek to integrate the individual into society.

There is a tradeoff between deterrence and rehabilitation. By rehabilitating the offender the CJS lowers the deterrence effect. The negative payoffs cannot be as large with a satisfactory rehabilitation program.

Community Response

There are usually two parties to a criminal event: the offender and the victim. (The exception is "crimes without victims" such as gambling.) The set of victims represents the impact of crime on the community. This becomes input for private and civic action. Citizens may arm themselves, private group might hire special police to react to criminal events.

The community (individuals, civic groups, businesses) may decide to react through the democratic process. That is, have government legislate new programs to alter social-psychological-economic variables or commit more resources to the CJS. They may, in addition, affect the opportunity distributions through laws (cars shall be locked, banks must have detection cameras) or by their own behavior.

Figure 1-5 summarizes the Criminal Justice System discussion in an expanded, integrated schematic that approximates the interactions of subsystems within the Criminal Justice System.

MODEL OF A POLICE SYSTEM

This section focuses in more detail on the police contribution to the crime control function. Police System impact on the crime process occurs at four points: (1) Forcing function, (2) *Apriori* decision, (3) Decision to execute, and (4) Criminal event.

It will be convenient to analyze the major activities of the police system in terms of three sub-systems:

- Response Force
- Preventive Force
- Follow-up Force

Police response to a criminal event can be differentiated with respect to the detection process. Detection is defined as the identification of a criminal event. The criminal event detection by a person or by the police. In the model all non-police detection will be considered as person originating. When a person detects a crime, he initiates a call for service to the police department. If the police, through offensive tactical patrol, detect a crime-in-progress, the person feedback loop need not be actuated. For "crimes without victims" (gambling, etc.), the detection process is carried out by specialized police unit.

The Response Force is defined as the police subsystem which responds to calls for service. These calls for service are generated by criminal events, public service demands and reports of suspicious activities. Public service demands consists of calls such as sick and injured transport, animal rescue and locating missing persons. Reports on suspicious activities are an important factor in being able to detect crime-in-progress. It also is an indicator of community cooperation in fighting crime. Chicago has a campaign called "Operation Crime Stop" to encourage this citizen participation. (See Figure 1-6)

The probability that the Response Force will apprehend the offender is a function of the time elapsed since the crime was committed and the tactic used. The elapsed time consists of:

(1) Time until citizen detects event and initiates call to the police department.

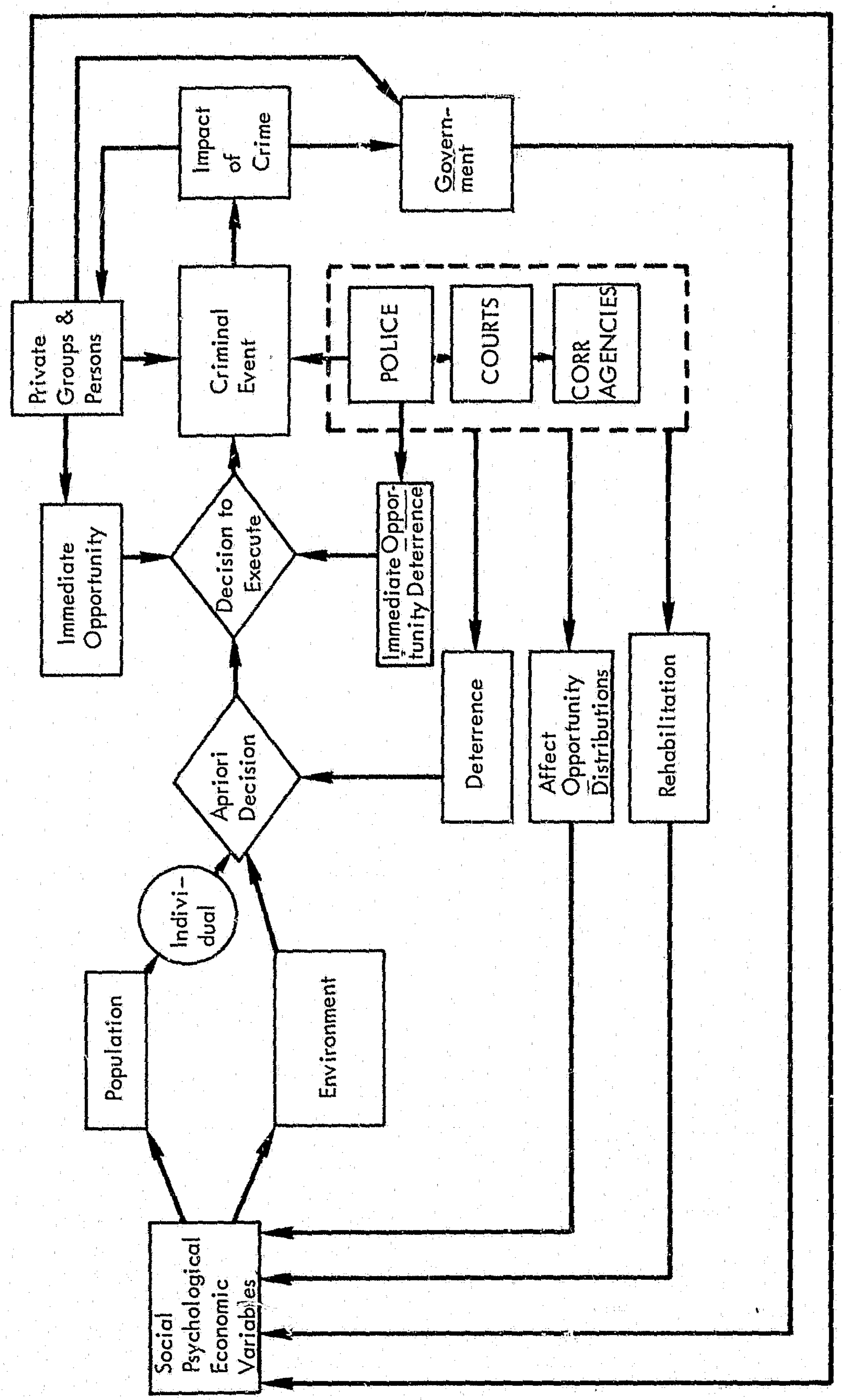
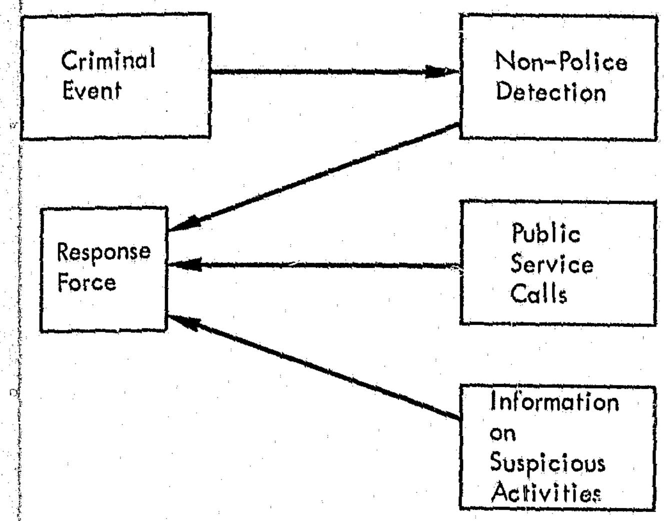


Figure 1-5 : Expanded View of the Criminal Justice System

Figure 1-6 : Inputs to the Response Force



(2) Processing time by the Communications Center.

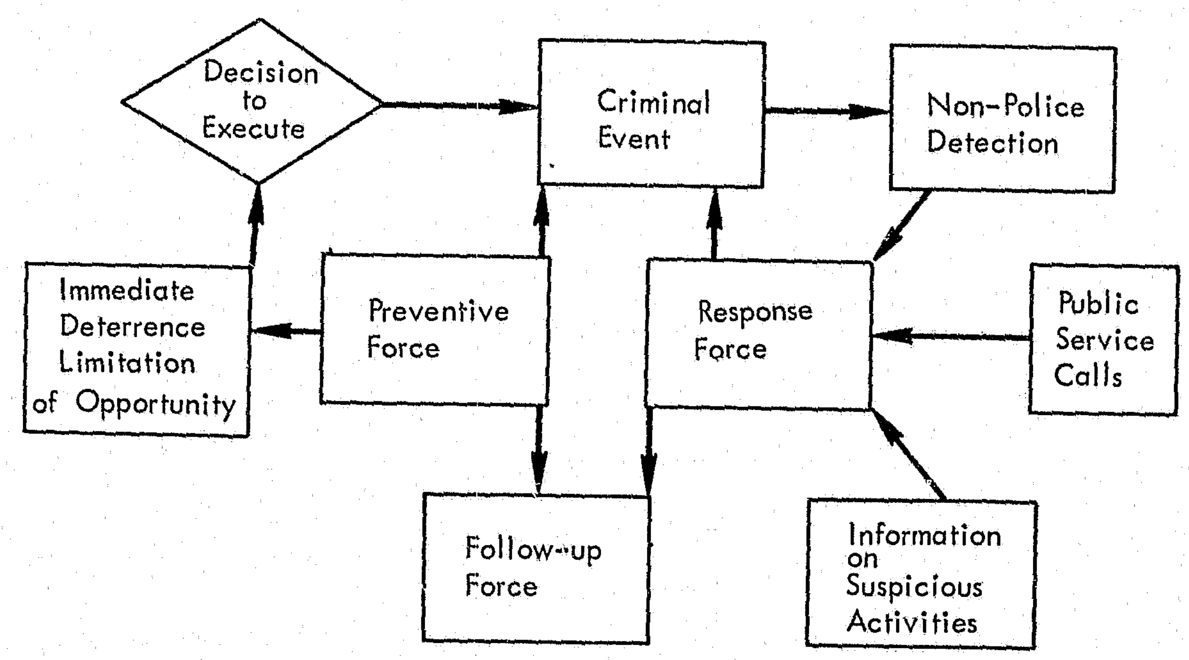
(3) Travel time for the assigned cars.

It has been shown that the apprehension probability is a decreasing function with respect to elapsed time.[9]

It is possible to initiate campaigns which stimulate citizens to be sensors for the police department and impress upon them the necessity of transmitting the information in a timely manner. This activity might very well have a larger potential payoff than optimization of police detection or response.

Analysis of the effectiveness of the Reactive Force is of great importance. Police departments are being offered hardware such as car locators and computerized communications centers but have presently no means to evaluate the benefits. How much will the proposed hardware decrease response time and how will this affect the probability of apprehension?

Figure 1-7 : Further Development of Police Systems Inputs and Outputs



Finally, how much is an increase of the probability of apprehension worth?

The Preventive Force is the offensive force in the combat against crime. It interacts with the crime process in two ways. It seeks to detect misconduct and apprehend the offender. It also influences the decision to execute a criminal event by affecting the perceived presence of police. For example: have policemen in uniform and marked cars or by otherwise give the potential offender an impression of police omnipresence.

This can come about through actual presence as a result of successful positioning of forces in time and space or through propaganda.

The Preventive Force also may affect the decision to execute by restricting actual opportunity, either by removing it completely or changing the factor of availability. This would be done through premise check, checking parked cars for valuables, removing drunks from the street, etc.

The Follow-up Force is the third sub-system. Its function is to apprehend criminals through the investigative process. It also includes the actions on a case following the booking of an offender.

Fig. 1-7 illustrates the interactions of these three forces in police functions.

Police system outputs

The outputs of the Reactive Force are arrest and public service. The probability of arrest was expressed as a function of elapsed time and tactics used. The Preventive Force outputs are arrests and impact on the decision to execute. The probability of apprehension is a function of elapsed time, probability of detection (i.e. being at the scene of the event, and recognizing that an event did in fact occur) and tactics used. Follow-up can be characterized by the probability of arrest through investigation. It is dependent on elapsed time and methods used. All of the above functions are also dependent on the type of crime. The tradeoff between the Response and Preventive Forces, given a criminal event, is that the latter may detect an event with a low probability but may have a higher probability of apprehension (due to shorter elapsed time).

Deterrence is an input to the *apriori* decision point. The Police System variable is the probability of arrest for the system (i.e. the combined efforts of all three sub-systems).

The Police System does affect the forcing function by changing the mechanisms generating opportunities. It can also affect an individual's utility functions through rehabilitation measures, mainly with respect to juveniles. This group of offenders is given special attention in order to influence them away from a criminal career. For example, special youth officers handle the cases and often a station adjustment is made.

The conceptual model can account for Community Relations programs. The Police System can influence the crime generation process by devoting resources to communication with private groups and individuals. These measures would influence community support and, hopefully, encourage the community to assist the police in the apprehension process and, even more importantly, affect the generative process of crime. These communication links can be called Human Relations with respect to individuals, and Community Relations with regard to groups.

For a more thorough discussion of these phases of police activity, we recommend "Dilemmas of Police Administration" by James Q. Wilson in the September–October (1968) issue of *Public Administration Review.*[13]

An effective Community Relations program seeks to explain the crime generation process to the community, what the police role is, what it can be expected to do, and what the community can do.

There is also a link to other branches of Government, for the sake of completeness, to emphasize that police departments have to make other city, state and federal officials cognizant of Police problems, results and limitations.

In summary, the outputs of the Police System are:

1. Apprehension of offenders.
2. Impact of immediate environment on the criminal event.
3. Impact on *apriori* decision.
4. Rehabilitation measures.
5. Changing opportunity distributions.
6. Public service.
7. Community support.

The array of these relationships between the Police System, the larger Criminal Justice System and other governmental systems is illustrated in Fig. 1-8.

Police System Objectives

Three missions and specific outputs have been identified for the Police System. It remains to specify the objectives of the system.

The first mission is Protection of Life and Property and Maintenance of Peace and Order. It becomes

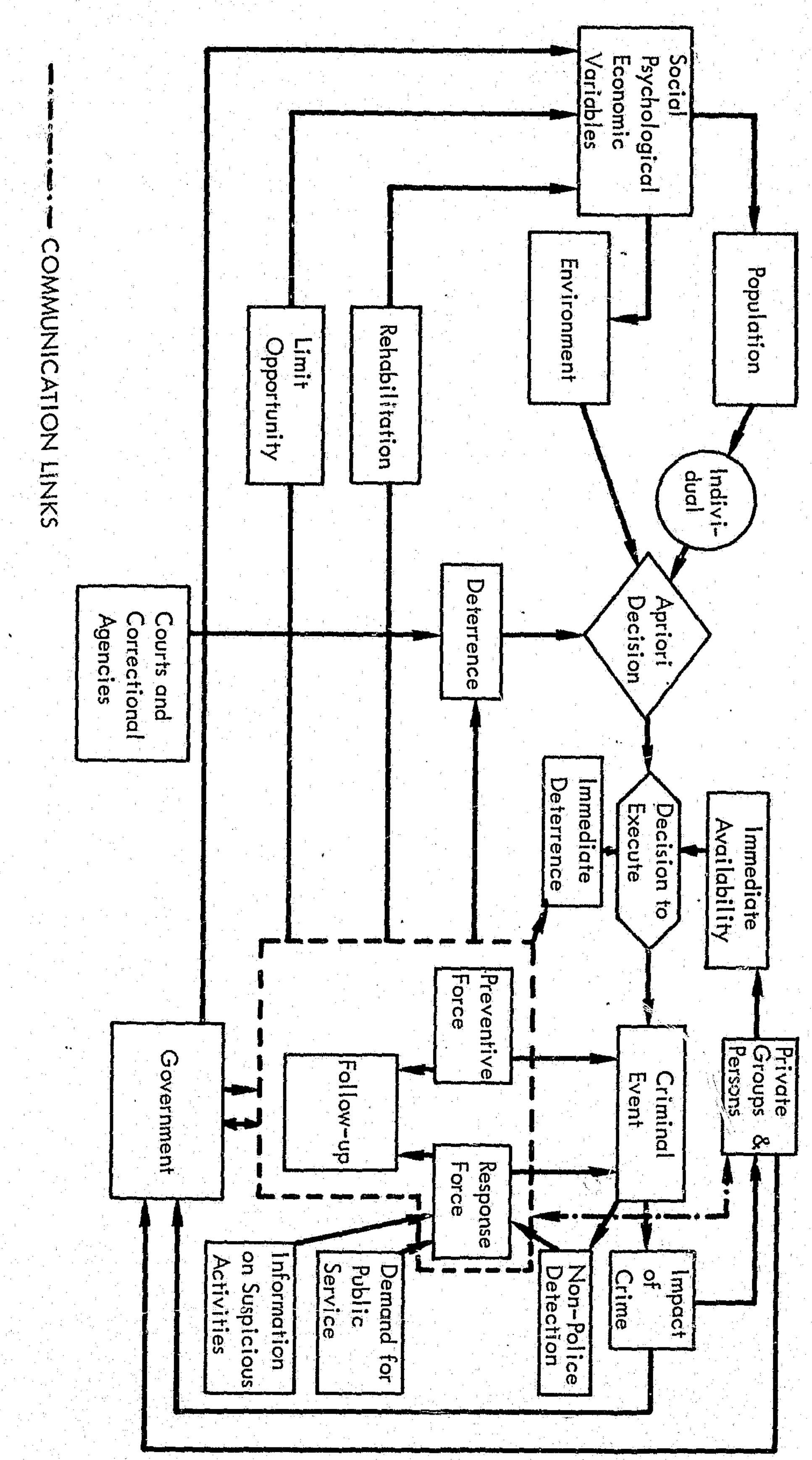


Figure 1-8 : Police Subsystem in the Criminal Justice System convenient to subdivide the broad notion of crime control into two classes of events as criminal events differ in degree of seriousness and the nature of police response. Crime will be defined as index crimes and hit-and-run accidents.

A second category of misconduct can be called Quasi-Criminal, whose objective contains activities devoted to the enforcement of city ordinances to a large degree. These are crimes of lesser seriousness than index crimes and the maximum sentence is a year in jail and/or a fine. The main offenses are disorderly conduct and drunkeness.

Maintenance of Peace and Order can be subdivided into an objective called Public Peace and one called Traffic Regulation. The Public Service and Community Support objectives conclude the list.

Mission	*Objective*
Protection of Life and Property	1. Crime Control
	2. Quasi-criminal Control
Maintenance of Peace and Order	3. Public Peace
	4. Traffic Regulation
Public Service	5. Public Service
Community Support	6. Community Support

These objectives can be compared with lists of objectives found in the literature.

The International City Managers Association listed five police objectives:[14]

- Prevention of Criminality
- Repressions of Crime
- Apprehension of Offenders
- Recovery of Property
- Regulation of Non-criminal Conduct

Another list includes:[15]

- Prevention of Crime
- Investigation of Crimes
- Apprehension of Violators
- Presentation of Criminals for Adjudication
- Services to the Public
- Enforcement of Non-criminal Ordinances
- Regulation of Activity within the Public Way

Peter Szanton defined the following objectives:[16]

1. Control and Reduction of Crime
2. Movement and Control of Traffic
3. Maintenance of Public Order
4. Provision of Public Service

The first two lists are not output-oriented in an independent manner and consequently would be difficult to use in a resource allocation analysis. Szanton's list is excellent but neglects the goodwill aspect. It has been said that a bulldozer is an effective crime fighter. This proposition would be a feasible alternative if there were no objective to represent the social system. For example, repressive police measures might prevent crime, but if individual's rights are destroyed in the process there should be a way of indicating this.

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CHAPTER 2

RESOURCE ANALYSIS BUDGET AS AN ALLOCATION TOOL*

Resource Analysis Budget is the name the Operations Research Task Force gave to a simplified planning-programming-budgeting system adaptable to the police department. This Resource Analysis Budget structures organizational activities into *output* categories. These output categories should:

1. Establish total money costs for achieving defined objectives.
2. Facilitate evaluation of alternative ways of achieving an objective.
3. Consider total costs for extended periods of time.
4. Facilitate cost-effectiveness analysis.

The complete Resource Analysis Budget provides a rational, coherent structure for analyzing resource allocation problems. It encompasses efficiency measures within programs and effectiveness measures between programs. Planning-Programming-Budgeting System (PPBS) is a modern budgeting system for planning, management and control. The PPBS ideas were developed at Rand Corp. in the early 50's. Secretary of Defense Robert McNamara and Charles J. Hitch applied the technique to the Department of Defense with such success that in August, 1965, President Johnson directed all other government agencies to use PPBS.[1] PPBS usually is compared with a line budget (i.e. government appropriations type budget) and a performance type budget and found to be clearly superior. A budget is a very versatile tool serving many purposes, and the difference among the different budgets lies in their emphasis.

BUDGETS AND THEIR PURPOSES

The line budget emphasizes control over inputs and usually follows the organizational structure. This type of budget is sufficient if one is not too concerned with the output of the organization and the production process is relatively uncomplicated. The performance budget is management oriented. It provides control and planning information for functional evaluation of organizational performance. It assesses work efficiency of operating units permitting cost control and estimation of resources needed to achieve a given output.

This opens the question of what the output of the organization should be. The PPBS is an output oriented budget which emphasizes planning. It seeks to provide a forum for resolving competing claims on the resources of the organization.[2] The obvious conclusion is that all of these types of budgets have useful functions in managing an organization.

Planning means the systematic consideration of objectives and alternatives. Programming incorporates the reduction of plans to specific resource requirements for an extended period of time. Budgeting consists of taking a one-year slice of the program budget.

Program budgeting characteristics are usually given as structural, analytical, and informational.[3]

At the heart of the PPBS is the structural or conceptual problem of what the end objectives are for the system, and what grouping of activities into pro-

Table 2–1

Rigg's Simplified Police Structure

I. Control of Criminal Behavior
   - A. Vice (Liquor, Narcotics, Prostitution, Gambling)
   - B. Rackets (Larceny, Loan Sharking, Organized Crime)
   - C. Crime Against Property
   - D. Crimes of Violence to Persons
     1. For profit
     2. Non-for-profit
   - E. Youth or Juvenile Crime

II. Public Service Activities
   - A. Emergency Medical Services
   - B. Security in Public Buildings
   - C. Traffic (Safety and Movement of Goods and Services)
   - D. Crowd Control
   - E. Inspection and Licenses
   - F. Control and Support

*Principal Authors: Ernst K. Nilsson and Sgt. Walter R. Gersch.

grams constitutes a logical and a helpful structure for decision making and analysis.

Analytical characteristics refer to the necessity for analysis of objectives and alternatives to develop a *relevant* flexibility for the decision maker. Intuition is not sufficient for analyzing complex alternatives or devising new ones.

Lastly, the PPBS functions as an information system for control (e.g. how well program costs are following budgeted costs) and for building a data base.

Table 2–2

Szanton's Program Budget*

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

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
  3. Testing, Evaluation, Promotion
- C. Public Relations
- D. Supporting Services
  1. Records (noncrime) and Data Processing
  2. Communications
  3. Budget
  4. Property

*From Appendix A, *Task Force Report: Science and Technology.*

The PPBS is no panacea. By projecting a structure onto a system, it emphasizes certain aspects and neglects others. A continual review of the overall system is necessary. The analysis of alternatives tends to emphasize the quantitative aspects and neglects the qualitative ones. However, good quantitative information is of optimum value if the decision maker keeps the qualitative dimension in mind.

PPBS AND POLICE FUNCTIONS

A few program budgets exist in the law enforcement literature. Dr. Riggs[4] defines only two major objectives for the police system: control of criminal behavior and public service activities (See Table 2-1). The program budget that ensues is somewhat simplistic and difficult to use as a structure for analysis because the programs follow the functional organization of a police department. These programs have very little relevance to analytical[5] output categories.

Peter Szanton[5] offers another program structure which is extremely detailed. Again it is deficient in that it separates output into functional categories. His budget also lacks a program to indicate relations with the environment.

It is difficult to devise a structure which is output-oriented and also provides a structure that is amenable to analysis. A functional structure is the obvious first step but, as has been pointed out, it really leads to a performance type budget. The hallmark of the program budget is its insistence on systematic analysis. (See Table 2-2)

RESOURCE ANALYSIS BUDGET: CHICAGO

The conceptual model has investigated police system activities and outputs with respect to Crime Control, Quasi-Criminal Control, Public Peace, Traffic, Public Service and Community Support. It remains to specify the program structure. It is convenient to define six major programs which contribute to achieving the six objectives. Much budgeting difficulty then is transferred to the subprogram structure. The key to the ensuing analysis is the police system model presented in Fig. 1-8.

Crime Control is influenced by social-behavioral-psychological factors, opportunity distributions, and risk. The police have activities directed to all of the above factors:

Objective: Crime Control
Program: Crime Control
Sub-Program:
1. Social-psychological-behavioral conditions;
2. Opportunity;
3. Risk.

However, police contribution to risk arises from the deployment of its three main forces, namely the Preventive, Response and Follow-up forces.

Different types of crime call for a different mix of police response. Burglary, for example, is best handled through a mix of preventive patrol and detective follow-up of stolen goods. There is very little that the response force can do. Consequently it is logical to provide sub-subprograms, with one program for each crime. At the present time very little has been done in determining the productivity of different forces with respect to index crimes.[6]

Quasi-criminal activity mainly includes disorderly conduct and drunkeness and needs no subdivision at the current state of knowledge. One of the main reasons for keeping it separate is to emphasize the need to consider other forms for handling these activities, such as hospital care and rehabilitation for drunks and social care for destitute persons. In other

Table 2–3

1968 Resource Analysis Budget, Chicago Police Department*

Program		*Cost*
Crime Control		$58,095,093
A. Social and Economic Conditions	$912,748	
B. Value:		
1. Opportunity		
2. Risk:		
(a) Prevention	30,271,342	
(b) Response	3,037,876	
(c) Followup	23,873,127	
Quasi-Criminal		5,182,802
Traffic Regulation		11,220,397
Public Peace		7,737,896
Public Service		14,883,191
A. Emergency	3,263,720	
B. Specialized	8,423,900	
C. Other	3,195,571	
Community Support		5,068,948
A. Community Relations	455,425	
B. Human Relations	177,944	
C. Public Relations	4,435,579	
Support		27,973,365
Total budget		130,161,692

*The 1968–69 cost figures for the Resource Analysis Budget were developed by Sgt. Walter R. Gersch of the Chicago Police Department. For more details, see Appendix B.

Table 2-4

1969 Resource Analysis Budget for the Chicago Police Department

Program		*Cost*
Crime Control		$69,928,966
A. Social and Economic Conditions	$1,052,270	
B. Value:		
1. Opportunity		
2. Risk:		
(a) Prevention	39,915,580	
(b) Response	3,599,454	
(c) Followup	25,361,662	
Quasi-Criminal		6,194,343
Traffic Regulation		13,108,235
Public Peace		8,824,134
Public Service		17,562,543
A. Emergency	3,821,518	
B. Specialized	9,919,179	
C. Other	3,821,846	
Community Support		7,220,547
A. Community Relations	727,586	
B. Human Relations	191,438	
C. Public Relations	6,301,523	
Support		31,329,763
Total budget		154,168,531

words, is the police department and jail the "best" way to handle these demands for social response?

Traffic regulation is often a separate entity within the police department. If this is the case, it will be convenient to consider it a separate program with the traffic contributions of the beat car force added to those of the Traffic Division.

The Public Peace program serves to highlight the

Figure 2-2 : 1969 Distribution by Program

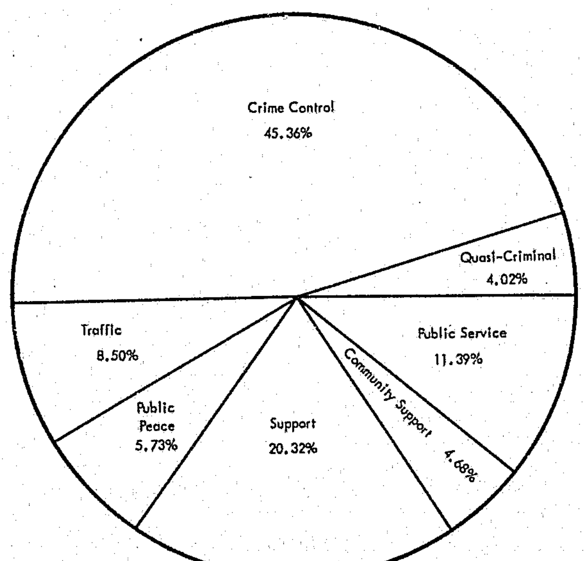
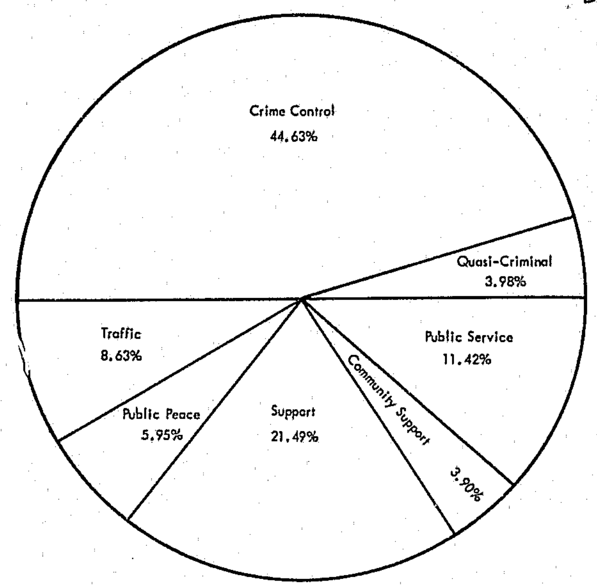


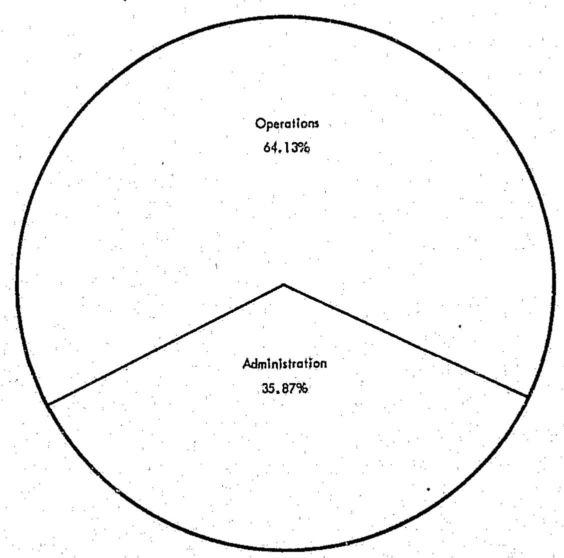
Figure 2-1 : 1968 Distribution by Program



following issues: should the police department provide resources for peaceful crowd control, such as parades and sporting events? What is the police role in a civil disturbance, and what commitment need the local police force make?

Public Service can be divided into three categories. Again the purpose is to highlight the commitment of resources and force a consideration of the cost of providing these services. The police department provides emergency services, such as sick transport.

Figure 2-3 :
1968 Operations-Administration Costs



Should it have this function? The fire department or a special division in a public safety program or a private firm could provide these as well. Specialized services became a separate program to include large activities such as marine patrol, animal care, auto pounds, license investigators, etc.

Lastly, community support represents unilateral and bilateral efforts by the police department to foster goodwill. Community Relations represent efforts directed towards reaching groups, and Human Relations are activities towards contacting individuals. Public Relations would represent the costs of improving, unilaterally the police image.

Figure 2-4 :
1969 Operations-Administration Costs

Support is a traditional category which includes general overhead and support activities such as the Superintendent's staff, the Communications Center, Records, Data Processing, maintenance of departmental vehicles, buildings, and radios, etc.

Comparable budgets, arranged for purposes of resource analysis, are shown for the Chicago Police Department in 1968 and 1969. Tables 2-3 and 2-4 show the dollar amounts while Figs. 2-1 through 2-4 give the relative percentages allocated to various functions.

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3 Examples of the development of these characteristics may be explored further in several Rand Corp. documents, including: Roland N. McKean and Melvin Anshen, *Problems Limitations and Risks of the Program Budget* (RM 4377-RC, 1965); David Novick, *Program Budgeting: Long Range Planning in the Department of Defense* (RM 3359-ASDC, Nov. 1962); E. S. Quade, *Systems Analysis Techniques for Planning-Programming-Budgeting* (P-3322, March 1966).

4 Robert Riggs, "A Planning-Programming-Budgeting System for Law Enforcement," *Law Enforcement Science and Technology* (Chicago: Academic Press, 1967), Vol. 1.

5 Peter Szanton, Ref. No. 16, Chapter I.

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CHAPTER 3

*ALLOCATING POLICE PATROL RESOURCES**

The challenge facing a police department is to obtain maximum efficiency and effectiveness in deploying police manpower resources. The police administrator views this challenge as an absolute reduction in crime on a city-wide basis. The desired goal would be complete eradication of crime; a realistic goal would be to recognize the existence of "irreducible minimum levels of criminal activity" and apply resources to contain crime in any area at this level. No estimate of the irreducible minimum level is given for any area—it is purely conceptual.

Crimes known to the police bear an unknown relationship to actual total criminal activity. This fact tends to weaken the concept of an irreducible minimum or a practical minimum to levels of criminal activity.

The measures of effectiveness generally used by police departments are the number of crimes reported, the number of arrests, and the amount of stolen property recovered. Since the seriousness of such "index" crime varies, it is necessary to obtain each of these measures for every specific type of crime. Throughout this discussion, the concept of an irreducible minimum is being applied to each type of crime in an area.

In a broad view, reduction of criminal activity implies both a decrease in the number of criminals and in the crime rate. The courts and correctional agencies have major roles in deterring criminal activity and in rehabilitation. The police have no control over these agencies; in a sense, the police act as an agent for the courts and the correctional agencies.

Police productivity against crime is measured directly in terms of arrests and the recovery of stolen property. Fluctuations in the volume of calls for police service of given types could be used to assess police productivity if it is borne in mind that differences exist between actual crime rates and crimes known to the police.

This chapter deals with the problem of overall resource allocation. The analytical methods that produced the various allocation results reported here were difficult to find and to apply. Concepts of mathematical economics have been used, to the greatest extent possible, to reconcile the widely divergent factors of police operational realities, empirical observation, and social philosophy. Every attempt has been made to provide the background and rationale for the approach taken.

Although the police and the public administrator may not want to follow all the technical detail, the text and the general comparative statistics will show the results of various approaches to distributing patrol manpower. Since this is one of the first attempts, perhaps the first attempt, to reflect such diverse factors and considerations in a model of resource allocation, the tentative nature of the suggested allocations must be borne in mind.

This is an important chapter in the sense that it presents a spectrum of results that show the sensitivity to the underlying assumptions of the possible allocation of manpower. The police administrator is asked to consider the fact that significant differences in manpower allocation do stem from the weightings given the various operational and judgemental factors.

This chapter examines the overall effect on allocation of resources caused by varying the allocation criteria. There is no single criterion for allocation and the assertion that any of the variants discussed herein is best, is not made.

DISTRIBUTION OF MANPOWER AMONG WATCHES

Each police district reflects distinctive crime patterns. One distribution of manpower in a district approximates the time distribution of crime and calls for service as closely as possible. Attaining this goal presents scheduling problems and could necessitate watch differential pay rather than normal rotating watch assignments. There are advantages and disadvantages inherent in either approach.

The distribution of personnel to watches could be determined through using percentages in table 3-1. Obtain the sum of demands for all three watches using either (1) entries under "Part I" or (2) entries under "Total." The ratio of a watch total to the district total is the fraction of district manpower that should be assigned to a watch.

The business area in the 1st District, the "Loop," greatly distorts statistics such as index crimes per 100,000 population. The fixed population is estimated at 14,000, however, during the day this number increases to approximately 1,000,000. For this reason, allocation of manpower based on index crimes per 100,000 population must exclude the 1st District. The district will be held constant and the current assigned force of 374 personnel are deducted from the total manpower available for allocation in all criteria discussed.

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Equalized Per Capita Police Service

A constant ratio of police to population is assumed a fair distribution with respect to cost to the taxpayer. This distribution does not consider the existence of neighborhood characteristics which are conducive to high incidence of crime in an area. Distribution of the patrol force as determined by application of this population criterion is given in percentages in Table 3-2.

Table 3-1

Distribution of Manpower by watch and Index Crime
[Based on a summary of Friday activity in Summer, 1963]

District	1st watch		2nd watch		3rd watch	
	Part I[1]	Total[2]	Part I	Total	Part I	Total
1	10.5	16.2	41.5	42.6	41.9	41.2
2	21.8	19.8	34.6	29.0	43.6	51.2
3	23.4	21.4	36.5	28.4	44.1	50.3
4	18.4	17.4	39.8	31.1	41.8	51.5
5	24.7	18.5	34.3	31.1	41.0	50.3
6	20.2	18.4	40.2	30.5	39.6	51.1
7	19.7	16.3	38.0	30.2	42.4	53.5
8	17.4	15.1	40.5	31.3	42.2	53.4
9	21.5	16.5	44.6	30.6	33.9	52.9
10	18.9	16.3	38.6	30.8	42.5	52.9
11	19.3	18.5	39.2	30.3	41.5	51.2
12	16.7	16.7	43.5	34.4	39.9	48.9
13	14.9	15.9	41.6	30.8	43.5	53.3
14	20.1	14.5	37.8	30.8	42.1	54.7
15	19.2	17.6	41.4	32.7	39.4	49.7
16	20.0	14.7	42.0	33.7	38.0	51.6
17	15.4	15.4	46.1	34.8	38.6	39.9
18	-16.4	19.5	43.5	32.8	40.1	47.8
19	16.6	18.3	43.1	29.7	40.3	52.1
20	15.5	18.6	46.8	31.3	36.7	50.1
21	16.7	18.5	41.1	31.7	42.2	49.7

[1] Index crimes.
[2] Total police service.

Table 3-2

Distribution of Force by Equalized per Capita Service

District	Percent	District	Percent
2	.044	12	.036
3	.049	13	.040
4	.048	14	.052
5	.050	15	.056
6	.046	16	.059
7	.044	17	.048
8	.067	18	.038
9	.050	19	.058
10	.048	20	.082
11	.035	21	.037

Equalized Density of Police Service

This criterion (Table 3-3) considers only the number of police per square mile. It does not consider land use, population homogenetics, or social and economic conditions.

INDEX CRIME "THREAT" ALLOCATION

This patrol force assignment criterion recognizes the existence of social and economic differences within the city. Table 3-4 shows index crime by type, district and area. It indicates the ratio of incidents per 100,000 population. In addition to the uncertainties that exist about the extent of crime "known" to the police, the use of Index Crime as an allocation method assumes that citizens view all index crimes as equally repre-

Table 3-3

Distribution by Equalized Density of Service

District	Square miles	Percent
2	4.313	.019
3	5.522	.024
4	26.309	.116
5	20.036	.088
6	16.225	.071
7	6.534	.029
8	23.609	.104
9	13.164	.058
10	7.207	.032
11	4.750	.021
12	6.282	.028
13	5.153	.023
14	7.752	.034
15	11.948	.052
16	28.417	.125
17	10.540	.046
18	4.250	.019
19	5.703	.025
20	11.637	.051
21	4.998	.022

Table 3-4

Index Crimes by Type—Offenses by District and Area*

	Murder			Rape			Robbery			Aggravated assault		
	1966	1967	1968	1966	1967	1968	1966	1967	1968	1966	1967	1968
District 1	5	5	14	8	14	17	449	506	525	167	160	200
District 2	65	69	99	154	160	181	2,866	2,553	2,836	1,859	1,949	1,898
District 21	29	39	45	99	98	79	1,285	1,317	1,325	840	832	652
Total, area 1	99	113	158	261	272	277	4,600	4,376	4,686	2,866	2,941	2,750
District 3	41	57	72	149	163	117	1,729	1,696	1,314	1,126	1,051	769
District 4	16	12	11	19	25	21	306	306	378	226	149	156
District 5	18	24	18	57	66	44	482	535	587	367	281	195
District 6	6	12	15	42	55	44	372	568	401	255	243	176
Total, area 2	81	105	116	267	309	226	2,889	3,105	2,680	1,974	1,724	1,296
District 7	33	40	67	104	132	114	1,298	1,071	1,161	1,088	1,034	1,174
District 8	1	2	6	19	11	13	219	224	220	162	132	156
District 9	24	16	19	21	23	12	405	346	312	354	307	296
Total, area 3	58	58	92	144	166	139	1,922	1,641	1,693	1,604	1,473	1,626
District 10	55	57	50	141	177	106	1,080	1,407	1,492	1,024	973	1,042
District 11	62	56	54	145	113	126	1,459	1,718	1,882	1,269	1,262	1,331
District 12	33	27	37	51	58	36	1,050	1,440	1,477	751	714	730
District 13	38	27	41	56	68	68	1,002	1,043	1,143	1,018	845	950
Total, area 4	188	167	182	393	416	336	4,591	5,608	5,994	4,062	3,794	4,053
District 14	10	11	13	15	22	17	292	367	415	281	305	326
District 15	15	22	15	38	40	58	301	561	627	218	233	301
District 16	6	......	2	9	10	7	97	105	120	68	92	72
District 17	2	4	7	3	12	9	130	154	160	97	119	103
Total, area 5	33	37	37	65	84	91	820	1,187	1,322	664	749	802
District 18	31	30	24	40	65	83	1,092	1,449	1,591	754	762	808
District 19	10	16	14	32	39	38	360	471	482	357	404	445
District 20	12	22	22	41	46	36	446	537	559	455	499	532
Total, area 6	53	68	60	113	150	157	1,898	2,457	2,632	1,566	1,665	1,785
Total, citywide	512	548	645	1,243	1,397	1,226	16,720	18,374	19,007	12,736	12,346	12,312
Total, per day	1.4	1.5	1.8	3.4	3.8	3.4	45.9	50.3	52.2	35.0	33.9	33.8
Total, per hour	0.06	0.06	0.07	0.14	0.16	0.14	1.91	2.10	2.18	1.46	1.41	1.41

	Burglary			Theft $50 and over			Auto theft			Total index			Total index 100,000 population
	1966	1967	1968	1966	1967	1968	1966	1967	1968	1966	1967	1968	1968
District 1	483	432	353	1,361	1,489	1,523	739	741	805	3,212	3,347	3,437	343,700
District 2	1,762	2,203	2,117	712	787	892	1,771	2,181	2,009	9,189	9,902	10,030	6,468
District 21	1,279	1,407	1,481	961	954	722	1,251	1,334	1,424	5,744	5,981	5,728	4,440
Total, area 1	3,524	4,042	3,951	3,034	3,230	3,137	3,761	4,256	4,238	18,145	19,230	19,195	6,439
District 3	2,292	2,464	2,243	573	694	599	1,864	2,107	2,273	7,774	8,232	7,387	4,269
District 4	986	790	861	389	290	337	1,278	1,179	1,364	3,220	2,751	3,128	1,829
District 5	1,159	1,358	1,195	436	469	368	1,829	1,890	1,840	4,348	4,623	4,247	2,454
District 6	1,075	1,185	1,151	474	451	351	1,134	1,444	1,319	3,358	3,958	3,457	2,133
Total, area 2	5,512	5,797	5,450	1,872	1,904	1,655	6,105	6,620	6,796	18,700	19,564	18,219	2,679
District 7	1,780	2,261	2,378	703	800	801	1,863	2,027	2,182	6,869	7,365	7,877	5,081
District 8	994	1,020	899	538	567	510	1,313	1,260	1,213	3,246	3,216	3,017	1,289
District 9	996	823	767	440	447	539	1,366	1,189	1,097	3,606	3,151	3,042	1,738
Total, area 3	3,770	4,104	4,044	1,681	1,814	1,850	4,542	4,476	4,492	13,721	13,732	13,936	2,470
District 10	2,005	2,068	3,117	662	794	795	1,715	1,698	1,951	6,682	7,174	8,553	5,031
District 11	2,301	2,741	3,668	925	1,006	955	1,874	2,215	2,171	8,035	9,111	10,187	8,215
District 12	974	965	1,452	1,119	1,160	1,189	1,382	1,344	1,290	5,360	5,708	6,211	4,929
District 13	1,696	1,831	2,351	886	894	1,116	1,921	1,991	1,941	6,617	6,699	7,610	5,397
Total, area 4	6,976	7,605	10,588	3,592	3,854	4,055	6,892	7,248	7,353	26,694	28,692	32,561	5,814
District 14	1,103	1,306	1,261	665	642	754	1,254	1,270	1,336	3,620	3,923	4,122	2,277
District 15	1,183	1,424	1,808	489	367	542	1,549	1,593	1,713	3,793	4,240	5,064	2,570
District 16	838	834	806	537	588	697	714	896	904	2,269	2,525	2,608	1,266
District 17	906	971	872	795	815	822	1,055	1,064	941	2,988	3,139	2,914	1,714
Total, area 5	4,030	4,535	4,747	2,486	2,412	2,815	4,572	4,823	4,894	12,670	13,827	14,708	1,950
District 18	1,615	1,499	1,615	1,648	2,024	2,090	1,850	2,024	1,929	7,030	7,853	8,140	6,120
District 19	1,880	1,691	1,785	1,193	1,288	1,344	1,459	1,484	1,589	5,291	5,393	5,697	2,820
District 20	2,177	2,035	1,964	1,949	1,951	1,909	1,765	1,528	1,486	6,845	6,618	6,508	2,251
Total, area 6	5,672	5,225	5,364	4,790	5,263	5,343	5,074	5,036	5,004	19,166	19,864	20,345	3,255
Total, citywide	29,484	31,308	34,144	17,455	18,477	18,855	30,946	32,459	32,777	109,096	114,909	118,966	3,418
Total, per day	81.0	86.0	93.8	48.0	50.8	51.8	85.0	89.2	90.0	299.7	315.7	326.8	9.39
Total, per hour	3.37	3.58	3.92	2.00	2.11	2.16	3.54	3.71	3.75	12.45	13.15	13.62	0.38

* For 364 day police year—13 police periods of 28 days each.

hensible. This assumption has been proven false by Selin and Wolfgang.[1]

Table 3-5 shows how the percentage distribution of total manpower would be affected if allocation was based on index crimes per 100,000 population.

VICTIM-ORIENTED DISTRIBUTION

Representative weights of the seriousness of index crimes as perceived by potential victims were reported by Sellin and Wolfgang as follows:

Homicide	26
Rape	12
Robbery	7
Aggravated Assault	7
Burglary	3
Theft ($50 or over)	3
Auto Theft	2

Victimization studies have not been undertaken in Chicago, thus it is unknown whether this rating scale is specifically applicable. Since Chicago is a collection of neighborhoods having distinct ethnic, cultural, and economic attributes, it may be assumed that each community within the city probably has a unique scale of values.

Prior to utilizing this allocation method, a statistically controlled survey of the attitude of individuals in each police district should be completed. The results of the survey will ascertain weights attached to various crimes by citizens in each district.

Following is one way to estimate weighted index crime in relation to potential victims:

1. From Table 3-4, take the number of index crimes of each type occurring in each district.
2. Multiply by the weight appropriate to that crime as determined by the attitude survey.
3. Total all weighted index crimes for the district.
4. The proportion of total available manpower

Table 3–5

Distribution of force by Index Crimes

District	*Percent*	*District*	*Percent*
2	.090	12	.069
3	.059	13	.075
4	.025	14	.031
5	.034	15	.035
6	.024	16	.017
7	.071	17	.024
8	.018	18	.086
9	.024	19	.039
10	.070	20	.031
11	.114	21	.062

required in relation to population density can be determined by dividing the total weight of index crimes for the district by the district population.

THE SHOUP-DOSSER MODEL

An interesting problem in the use of an urban police force arises in considering how to best assign patrolmen to police districts so as to cause the average crime rate in a city to be as small as possible. A simple mathematical model for achieving this distribution is presented by Shoup[2] and Dosser[3].

The average crime rate is defined as the number of crimes of a specific type committed over a time period, such as an hour or a day, or a police watch. This number is assumed known or readily calculable from police records. For sake of simplicity, we consider only one type of crime. Patrolmen are assumed to be equal in effectiveness from man to man. Since police districts vary in their physical make-up, population size, economic level and etc., the value of a patrolman in crime reduction varies from district to district.

The Shoup-Dosser model assumes the city to be divided into two districts (called one and two) with corresponding average crime rates Z_1 and Z_2. Since the effectiveness of a patrolman is different in each district, constant numbers k_1 and k_2 are defined to accommodate these differences. If t policemen are assigned to district one, they will have effectiveness tk_1. The larger tk_1, the greater the effectiveness of the t policemen in police district one. This means that if a single patrolman can control the crime rate better in district one than in district two, then k_1 will be larger than k_2 and, of course, tk_1 will be larger than tk_2. Now it is assumed further that when t policemen are assigned to district one, the average crime rate in that district is reduced to Z_1/tk_1. Therefore, the total average rate (under the two-district assumption) for the city is

$$\frac{Z_1}{tk_1}+\frac{Z_2}{(T-t)k_2} \tag{1}$$

where there are a total of T patrolmen to be distributed.

The problem now is to assign the t and $T-t$ policemen to districts one and two respectively so as to minimize the total average crime rate given by Expression 1.

Of course the more meaningful problem, applicable to a large urban police force like that of the City of Chicago, is to determine the best distribution of T policemen over a city with *many* police districts. We will now address ourselves to the more general solution.

General Solution

Consider the following definitions:

- n: number of police districts in the city.
- i: the police district number $i=1, \dots, n$.
- Z_i: average number of crimes (per unit time) in police district i $(i=1, \dots, n)$.
- k_i: an effectiveness constant for a patrolman in district i.
- t_i: the number of patrolmen assigned to district i.

The object is to minimize the total average crime rate in the city with a fixed total police force of T. Therefore, we wish to minimize

$$\sum_{i=1}^{n} \frac{Z_i}{t_i k_i} \tag{2}$$

subject to

$$\sum_{i=1}^{n} t_i = T. \tag{3}$$

Form

$$F=\sum_{i=1}^{n} \frac{Z_i}{t_i k_i}+\lambda\left(\sum_{i=1}^{n} t_i - T\right) \tag{4}$$

and obtain the set of $n+1$ equations

$$\frac{\partial F}{\partial t_i}=-\frac{Z_i}{t_i^2 k_i}+\lambda=0, \quad i=1, \dots, n. \tag{5a}$$

$$\sum_{i=1}^{n} t_i - T=0 \tag{5b}$$

From (5a) it follows that,

$$t_i=\sqrt{\frac{Z_i}{\lambda k_i}} \quad i=1, \dots, n. \tag{6}$$

and

$$\sum_{i=1}^{n} t_i^2=\sum_{i=1}^{n} \frac{Z_i}{\lambda k_i}. \tag{7}$$

Solving for λ in expression (7) gives,

$$\lambda=\frac{\sum_{i=1}^{n} \frac{Z_i}{k_i}}{\sum_{i=1}^{n} t_i^2}. \tag{8}$$

Now

$$\sum_{i=1}^{n} t_i^2=T^2-2\sum_{i<j} t_i t_j. \tag{9}$$

From (6)

$$t_i t_j=\frac{1}{\lambda}\sqrt{\frac{Z_i Z_j}{k_i k_j}}. \tag{10}$$

Substituting (10) into (9) and then substituting (9) into (8) gives

$$\lambda=\frac{\sum_{i=1}^{n} \frac{Z_i}{k_i}}{T^2-\frac{2}{\lambda}\sum_{i<j}\sqrt{\frac{Z_i Z_j}{k_i k_j}}}. \tag{11}$$

Solving (11) for λ gives

$$\lambda=\frac{\sum_{i=1}^{n} \frac{Z_i}{k_i}+2\sum_{i<j}\sqrt{\frac{Z_i Z_j}{k_i k_j}}}{T^2}$$

$$=\frac{1}{T^2}\left(\sum_{i=1}^{n}\sqrt{\frac{Z_i}{k_i}}\right)^2. \tag{12}$$

Finally substituting λ from (12) into (6) gives the optimum distribution of the t_i over the n districts to minimize the average crime rate,

$$t_i=T\frac{\sqrt{\frac{Z_i}{k_i}}}{\left(\sum_{i=1}^{n}\sqrt{\frac{Z_i}{k_i}}\right)} \quad \text{for } i=1, \dots, n. \tag{13}$$

Interpretation

Let $n=2$ (only two districts), $k_1=k_2$ and $Z_1=Z_2=Z$, it follows that

$$t_1=t_2=T\frac{\sqrt{Z}}{2\sqrt{Z}}=\frac{T}{2}. \tag{14}$$

With no loss of generality, we let $k_1=k_2=1$ in (14).

This solution can be interpreted as follows: when there are only two districts which are identical with regard to mean crime rate and unit police effectiveness within each district (i.e., $k_1=k_2=1$) the minimum average crime is obtained when the T policemen are assigned $T/2$ to each district. This gives

$$C=\frac{Z}{T/2}+\frac{Z}{T/2} \tag{15}$$

$$=\frac{2Z}{T/2}. \tag{16}$$

Now consider the two districts with identical mean crime rates (per unit time) and identical unit police effectiveness $(k_1=k_2=1)$. If we put the two districts together, we obtain a new district whose mean crime rate is $2Z$ (per unit time). If we originally confronted this composite district and had T policemen to allocate, we would calculate the resultant minimum rate as

$$\frac{2Z}{T}. \tag{17}$$

However, this does not agree with the statement in (16). If we agree that (16) is logically correct, then the result $2Z/T$ cannot be a correct solution for the composite district which must be identical to the sum of two districts. This prompts us to reconsider the concept surrounding expression (16). If we consider Z as the average crime rate in the presence of one policeman, then Z/t is the average crime rate in the district in the presence of t policemen. It follows that $2Z$ is the average crime rate in the two districts, each characterized by $Z_1=Z_2=Z$ and $k_1=k_2=1$, in the presence of *two* policemen. Then given the composite rate $2Z$ (from two identical districts) we allocate the policemen optimally by assigning $T/2$ *pairs* of policemen to the composite district. This concept is consistent with the solution in expression (16).

In future considerations, we shall refer to Z_i as the mean crime rate in district i in the presence of one policeman.

An allocation using city-wide minimization of crime to guide the distribution of manpower is derived from a simple extension of the Shoup-Dosser method.

Table 3-6

Comparative Allocations of Police Manpower

District	Current	Equalized per capita	Equalized density	Index crime per 100,000
2	487	295	137	604
3	422	329	161	396
4	241	322	778	168
5	263	335	590	228
6	224	309	476	161
7	450	295	195	476
8	241	449	698	121
9	305	335	389	161
10	361	322	215	470
11	378	235	141	765
12	332	241	188	463
13	337	268	154	503
14	264	349	228	208
15	271	376	349	235
16	224	396	838	114
17	167	322	309	161
18	411	255	127	577
19	291	389	168	262
20	330	550	342	208
21	335	248	148	416

Effect of Allocation Criteria

The sensitivity of the manpower distribution of a patrol force to the criteria selected is shown in Table 3-6. Each column of figures represents the distribution of manpower in each district according to which one of the several criteria is emphasized. Although these figures do not indicate the allocation between the three watches, they permit a comparison of the overall manpower shifts which can occur as a function of a chosen criterion.

Service and Index Criteria

Chicago Police Department policy calls for maximum service to the citizens. Under that policy, the criterion for allocation should be total calls for service on the third watch on Friday, when there is peak demand. When total calls for service or a weighted workload are used in setting criteria, areas which have a heavy volume of calls but less index crime receive more resources.

From an earlier table (Table 3-1) we have percentages of both Index Crimes and total service demands by districts. Using Part I or Index Crime calls for service or total calls for service produce different allocations of manpower. Reliance on Index Crime calls naturally tends to increase the allocation of patrol force to areas with a high incidence of index crime.

Table 3-7 reflects the allocation of the 6,708 members of the patrol division in Chicago where the following criteria are used:

1. Part I calls for service on the third watch Friday.
2. Total calls for service on the third watch Friday.
3. Part I calls for service on the third watch Saturday.
4. Total calls for service on the third watch Friday.
5. Part I calls for service on the third watch All days.
6. Total calls for service on the third watch All days.
7. Weighted workload service on the third watch All days.

For the purpose of comparison, current allocations of manpower by district are included in Table 3-7.

Table 3-7

Manning of Districts Based on Minimizing Crime if Part I Crime, Total Service or Weighted Workload Dominate

District	Current	Friday		Saturday		All days		
		Part I	Total	Part I	Total	Part I	Total	Weighted workload
1	374	320.6	298.4	331.4	271.7	317.7	287.3	312.2
2	487	344.3	339.0	357.2	350.7	332.4	343.5	343.4
3	422	251.2	308.7	268.3	325.1	267.0	321.2	315.8
4	241	302.6	257.2	314.6	260.6	301.7	263.4	256.6
5	263	325.0	301.9	328.0	306.2	320.3	307.1	301.3
6	224	277.6	286.4	277.9	283.7	279.8	285.6	278.8
7	450	344.8	309.7	364.7	316.2	349.0	268.5	310.6
8	241	235.1	249.7	228.8	240.7	234.6	246.4	233.8
9	305	234.1	312.4	254.0	311.5	243.3	312.6	293.9
10	361	431.8	380.1	421.6	381.4	410.1	379.6	378.0
11	378	504.5	372.1	484.5	377.1	481.8	372.3	372.5
12	332	345.9	398.2	334.2	394.9	329.4	393.1	405.1
13	337	395.7	368.9	389.1	374.5	393.5	375.4	372.1
14	264	318.4	340.3	297.6	334.5	312.5	342.3	329.5
15	271	332.0	323.0	307.2	320.3	326.9	324.8	320.4
16	224	174.7	167.6	170.5	159.8	184.8	166.3	163.6
17	167	274.0	260.0	253.7	250.4	280.7	260.7	255.1
18	411	305.8	336.7	315.8	333.0	312.9	337.3	356.3
19	291	373.2	402.8	370.8	401.8	392.7	409.1	396.1
20	330	273.6	397.5	288.1	412.1	293.4	408.8	401.8
21	335	342.9	297.4	349.9	302.0	343.5	302.6	311.1

Table 3-8

District Manning on Minimization Criterion

[Not weighted by population]

District	Friday		Saturday		All days		
	Part I	Total	Part I	Total	Part I	Total	Weighted workload
1	281.6	214.8	290.7	195.7	277.7	206.7	225.4
2	322.7	310.1	334.6	321.1	310.3	314.1	315.2
3	279.2	307.0	298.2	323.6	295.6	319.3	315.1
4	305.9	317.6	317.9	322.1	303.8	325.1	317.9
5	321.6	331.9	324.4	337.0	315.7	337.4	332.3
6	312.3	328.6	312.5	325.7	313.5	327.5	320.8
7	300.4	307.5	317.6	314.2	302.9	266.5	309.4
8	283.6	332.5	275.9	320.8	282.0	328.0	312.4
9	242.8	324.7	263.3	324.1	251.3	324.8	306.5
10	354.6	327.4	346.1	328.8	335.5	326.8	326.6
11	365.9	328.0	351.3	332.7	348.1	328.0	329.4
12	319.0	273.8	308.1	271.8	302.5	270.3	279.5
13	352.4	339.6	346.3	345.1	349.1	345.5	343.7
14	321.0	359.1	299.8	353.3	313.7	361.1	348.9
15	349.3	336.9	323.1	334.3	342.7	338.6	335.3
16	272.8	284.8	266.1	271.7	287.4	282.5	279.0
17	332.9	346.3	308.2	333.7	339.7	347.0	340.8
18	348.2	293.7	359.3	290.7	354.8	294.0	311.8
19	344.6	376.3	342.3	375.7	361.3	382.0	371.2
20	350.5	373.3	368.8	387.4	374.3	383.8	378.6
21	346.7	294.0	353.5	298.7	345.9	299.0	308.5

Minimization and Population

Other variations in manpower assignments of the patrol division are produced when the goal of minimizing crime is weighted with considerations of population in a district. In one case, Table 3-8, the total number of criminal events is considered without weighting by population. In Table 3-9, weighting of the criminal events by the district population produces significant shifts in manning practices both from the unweighted version and from current practices.

The effect of variation in the effectiveness of police in the different districts is shown in the results through application of the victim-oriented weightings of Selin and Wolfgang.

SPLIT-FORCE CONCEPT

An idealized objective for allocation of patrol resources is to have at any instant of time, the response force so designed that it exactly matches the demand for police service placed upon it. Simultaneously a preventive force could be allocated throughout the city in such a way as to minimize total criminal activity as defined in a victim oriented weighting system. When different neighborhoods place different weights or emphasis upon the kinds of enforcement desired, this variation should be recognized and normalized by the population in each district.

The question of allocation of preventive patrol assets involves many judgmental values. In deciding where, when, and how to use preventive patrol assets, the police administrator must evaluate the capabilities of his resources, the nature of the crime problems in various parts of the City, and the needs and desires of the people in the various neighborhoods with respect to law enforcement. Their needs and desires are communicated to the police through direct contact at functions such as police-community workshops and through contact with elected officials by members of the community.

Such "judgmental criteria" must also be combined with "operational criteria" or the realities of the size and availability of the police administrator's response force. In the next chapter, it will be shown, again, that the size of this response force is very sensitive to policies regarding response to calls for police service. Adopting a more austere policy toward response toward calls for service can release a sizeable number of units for assignment to what may be called an "aggressive preventive patrol." Thus the decision becomes one of appropriate allocation of resources between such preventive units and responsive units.

This choice leads into evaluation of a "split-force" concept. Chapter 5, dealing with preventive patrol, discusses the application of analytical methods to assess the effectiveness of preventive patrol in a few specific situations. In this chapter, the use of community oriented criteria for the gross assignment of preventive patrol forces is illustrated.

The split-force concept provides an approach to attainment of the objective. If the response force is designed city-wide as shown, then the problem remaining is to allocate the preventive assets. This allocation can be a two-step process. First the overall preventive force is distributed among the police areas or the 21 police districts. The second step is to allocate within the assigned geographical regions using techniques similar to those discussed in Chapter 5.

Even if the exact mathematical allocations are not followed, the existence of such objective allocation provides a rough yardstick for use in a police management information system.

ALLOCATING PREVENTIVE FORCE

It is recommended that preventive force units be distributed in accordance with the Shoup-Dosser method mentioned previously. However, in order to show explicitly how other considerations effect the allocation process, the discussion of the previous section will be amplified.

For simplicity, and to fix ideas, distribution of a total force of T between two districts is considered. If t_1 is the force allocated to preventive patrol in the district 1 and t_2 in district 2, then

$$\frac{t_1}{t_2}=\sqrt{\frac{Z_1K_2}{Z_2K_1}}$$

Where Z represents the crimes or their surrogate, the calls for service, and K is the relative effectiveness of the police in each district.

Table 3–9

District Manning on Minimization Criterion
[Weighted by population]

District	Friday				Saturday				All days					
	Part I	Percent	Total	Percent	Part I	Percent	Total	Percent	Part I	Percent	Total	Percent	Workload	Percent
1	374.0	.056	374.0	.056	374.0	.056	374.0	.056	374.0	.056	374.0	.056	374.0	.056
2	324.9	.051	310.8	[illegible]	337.8	.053	320.8	.051	313.1	.049	314.5	.050	316.0	.048
3	265.7	.042	290.7	[illegible]	284.5	.045	305.5	.048	281.8	.044	302.1	.048	298.6	.044
4	293.3	.046	303.1	.048	305.6	.048	306.4	.048	291.8	.046	310.0	.049	303.6	.045
5	306.0	.048	314.3	.050	309.5	.049	318.2	.050	300.9	.048	319.3	.050	314.9	.047
6	306.9	.048	321.4	.051	307.9	.049	317.7	.050	308.7	.049	320.1	.051	314.0	.047
7	302.5	.048	308.2	.049	320.7	.051	314.0	.050	305.6	.048	266.9	.042	310.3	.046
8	232.1	.037	270.9	.043	226.4	.036	260.6	.041	231.2	.036	266.9	.042	254.6	.038
9	230.1	.036	306.3	.048	250.2	.040	304.8	.048	238.6	.038	306.2	.048	289.3	.043
10	341.2	.054	313.5	.049	333.9	.053	313.9	.050	323.4	.051	312.7	.049	313.0	.047
11	411.5	.065	367.1	.058	396.1	.063	371.2	.059	392.2	.062	366.8	.058	368.9	.055
12	356.3	.056	304.4	.048	345.0	.054	301.3	.048	338.5	.053	300.2	.047	310.9	.046
13	371.7	.059	356.6	.056	366.3	.058	361.2	.057	368.9	.058	362.4	.057	361.1	.054
14	399.6	.063	445.0	.070	374.3	.059	436.5	.069	391.3	.062	447.0	.071	432.5	.064
15	312.0	.049	299.5	.047	289.4	.046	296.4	.047	306.6	.048	300.7	.047	298.2	.044
16	238.3	.038	247.7	.039	233.1	.037	235.6	.037	251.5	.040	245.5	.039	242.7	.036
17	320.0	.051	331.2	.052	297.0	.047	318.3	.050	327.1	.052	331.7	.052	326.2	.048
18	377.8	.060	317.1	.050	390.9	.062	313.0	.049	385.7	.061	317.3	.050	336.9	.050
19	303.5	.048	329.7	.052	302.2	.048	328.3	.052	318.7	.050	324.5	.053	325.5	.048
20	258.4	.041	273.9	.043	272.6	.043	283.4	.045	276.5	.044	281.4	.044	278.0	.041
21	382.3	.060	322.6	.051	390.8	.062	326.9	.052	382.0	.060	327.8	.052	338.7	.050

In an earlier discussion, it was suggested that the crimes or calls for service occurring in a district be normalized to the units of crimes in a district per policeman by dividing the observed numbers by the size of assigned force, which in the two districts is C_1 and C_2. Also, it is suggested that the concept of risk to the individual is served by dividing by population in the district, D_1 and D_2.

Inserting these factors into the initial discussion yields

$$\frac{t_1}{t_2}=\sqrt{\frac{Z_1K_2C_2D_2}{C_1D_1K_1Z_2}}$$

or, to simplify notations

$$\text{Let } Z_1^*=\frac{Z_1}{C_1D_1} \text{ so that}$$

$$\frac{t_1}{t_2}=\sqrt{\frac{Z_1^*K_2}{K_1Z_2^*}}$$

There is another refinement that should be made. The Z_1 comprise different kinds of crime, of calls for service that may have differing levels of seriousness to the citizens of the community. If in District 1 there are A crimes of weight a, B of weight b, C of weight c and so on, then the weighted crime index for the district is

$$Z_{1w}=aA+bB+cC+\cdots$$

and the optimal allocation becomes

$$\frac{t_1}{t_2}=\sqrt{\frac{Z_{1w}^*K_2}{K_1Z_{2w}^*}}$$

Generalizing the above to a distribution among all 21 police districts yields the formula for the ith district

$$t_i=\frac{T\sqrt{\frac{Z_{iw}^*}{K_i}}}{\left(\sum_{i=i}^{n}\sqrt{\frac{Z_{iw}^*}{K_i}}\right)} \quad \text{for } i=1,\cdots n$$

Where T is the entire force to be allocated, although it is a laborious process, it is feasible to carry out the entire computation using only a slide rule.

For hand computation purposes as well as for application of the technique to the allocation of any force size, Table 3-10 gives the value of the ratio of the two quantities under the square root sign in the form of a percentage. This is the percentage of the force that is to be distributed among all districts except the First Police District. Do not omit the subtraction of the fixed number of men that must be assumed for the First District due to the meaninglessness of normalization for the First District commercial, commuting population.

Table 3–10

Allocation Resulting From Consideration of All Factors Illustrates Effect of Assumption Concerning Effectiveness.
[Force size: 6708]

District	Equally effective		Effectiveness—Felony arrests/Police assigned	
	Men	Percent	Men	Percent
1	374.0	.056	374.0	.056
2	401.9	.063	350.1	.055
3	318.1	.050	258.7	.041
4	248.3	.039	216.8	.034
5	279.1	.044	260.1	.041
6	282.1	.045	282.0	.045
7	338.5	.053	282.6	.045
8	201.7	.032	139.4	.022
9	222.3	.035	202.7	.032
10	375.5	.059	386.1	.061
11	471.7	.074	540.5	.085
12	395.8	.062	616.1	.097
13	393.9	.062	429.3	.068
14	359.6	.057	455.8	.072
15	284.7	.045	258.6	.041
16	201.3	.032	120.7	.019
17	277.0	.044	270.1	.043
18	381.8	.060	409.1	.065
19	284.1	.045	274.1	.043
20	241.6	.038	182.3	.029
21	375.0	.059	399.0	.063

Estimating the effectiveness Factor K

All K are Equal. This condition asserts that a policeman is equally effective in any district. Given the variety of duties that a policeman performs, and given that the men of the patrol division who are assigned to police districts encounter only about 12% Part I crimes in responding to calls for service, the allocation based on equal effectiveness provides a good base case.

Effectiveness varies from district to district. Crime is not uniformly distributed in the city. Certain districts provide far more opportunity for all classes of arrests. District populations vary. The economically disadvantaged citizens are crowded into a few districts. Arrests for drunk and disorderly conduct and prostitution are concentrated in a few areas.

Base relative effectiveness on ratio of felony arrests to assigned manpower. The use of numbers of arrests is only one approach to establishing the output of police units. It is not possible to measure the number

Table 3–11

Relationship Between Arrests and Manpower, 1969

District	Relative weight	Total arrests	Relative weight
21	.52	3.34	.48
1	.69	6.3	.91
2	.61	3.9	.57
3	.43	3.3	.48
4	.52	2.1	.30
5	.54	2.7	.39
6	.42	2.5	.36
7	.70	3.3	.48
8	.37	1.8	.26
9	.49	3.0	.43
10	.79	4.4	.64
11	1.00	4.2	.61
12	.63	6.9	1.00
13	.67	3.9	.57
14	.52	2.9	.42
15	.48	3.0	.84
16	.22	1.1	.16
17	.36	6.8	.99
18	.41	.43	.62
19	.62	3.7	.54
20	.32	3.3	.48

of crimes prevented by police activity. It is not known how many crimes actually occur.

Furthermore, in terms of the total criminal justice system, the law enforcement component has no control over the final disposition of arrestees. The law

Table 3–12

Effect of Assumptions Concerning Effectiveness

[Force size: 7182]

District	Equally effective		Effectiveness—Felony arrests/Police assigned	
	Men	Percent	Men	Percent
1	374.0	.056	374.0	.056
2	432.0	.063	376.3	.055
3	341.9	.050	278.0	.041
4	266.9	.039	233.0	.034
5	300.0	.044	279.5	.041
6	303.2	.045	303.1	.045
7	363.9	.053	303.8	.045
8	216.8	.032	149.8	.022
9	239.0	.035	217.8	.032
10	403.6	.059	414.9	.061
11	507.0	.074	580.9	.085
12	425.5	.062	662.2	.097
13	423.4	.062	461.4	.068
14	386.5	.057	490.0	.072
15	306.0	.045	278.0	.041
16	216.3	.032	129.8	.019
17	297.7	.044	290.3	.043
18	410.4	.060	439.7	.065
19	305.4	.045	294.7	.043
20	259.6	.038	195.9	.029
21	403.1	.059	428.9	.063

Table 3–13

Effect of Assumptions Concerning Effectiveness

[Force size: 7760]

District	Equally effective		Effectiveness—Felony arrests/Police assigned	
	Men	Percent	Men	Percent
1	374.0	.048	374.0	.048
2	469.2	.063	408.7	.055
3	371.4	.050	302.0	.041
4	289.9	.039	253.1	.034
5	325.8	.044	303.6	.041
6	329.3	.045	329.2	.045
7	395.3	.053	329.9	.045
8	235.4	.032	162.7	.022
9	259.6	.035	236.6	.032
10	438.4	.059	450.7	.061
11	550.7	.074	631.0	.085
12	462.2	.062	719.3	.097
13	459.9	.062	501.2	.068
14	419.8	.057	532.2	.072
15	332.4	.045	302.0	.041
16	235.0	.032	140.9	.019
17	323.4	.044	315.3	.043
18	445.8	.060	477.6	.065
19	331.7	.045	320.1	.043
20	282.0	.038	212.8	.029
21	437.8	.059	465.9	.063

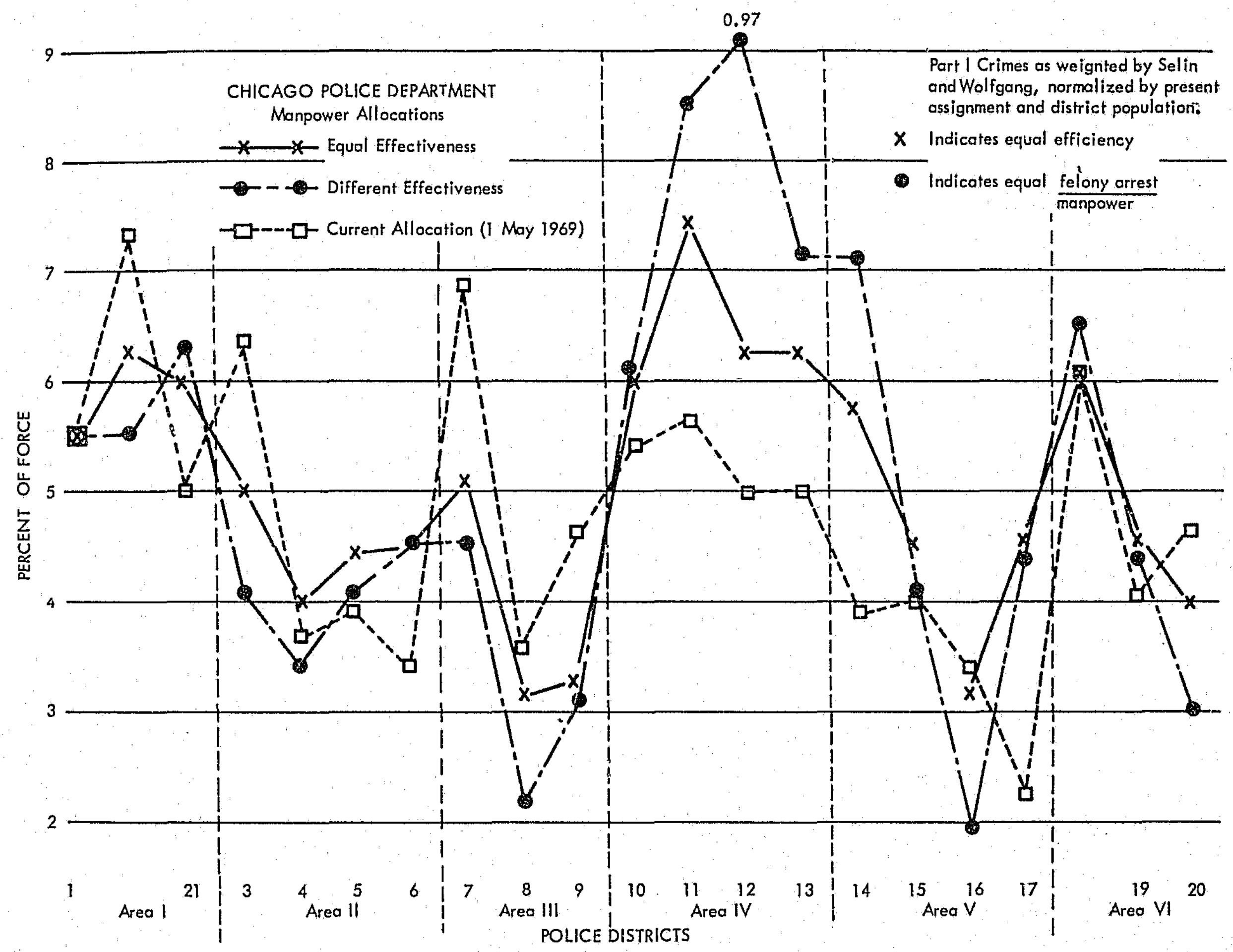
Table 3–14

Effect of Assumptions Concerning Effectiveness.

[Force size: 9188]

District	Equally effective		Effectiveness—Felony arrests/Police assigned	
	Men	Percent	Men	Percent
1	374.0	.041	374.0	.041
2	559.3	.063	487.1	.055
3	442.6	.050	360.0	.041
4	345.5	.039	301.7	.034
5	388.4	.044	361.9	.041
6	392.5	.045	392.4	.045
7	471.1	.053	393.3	.045
8	280.6	.032	194.0	.022
9	309.4	.035	282.0	.032
10	522.5	.059	537.2	.061
11	656.4	.074	752.1	.085
12	550.8	.062	857.3	.097
13	548.1	.062	597.3	.068
14	500.4	.057	634.3	.072
15	396.2	.045	359.9	.041
16	280.1	.032	168.0	.019
17	385.4	.044	375.8	.043
18	531.4	.060	569.3	.065
19	395.4	.045	381.5	.043
20	336.1	.038	253.6	.029
21	521.8	.059	555.3	.063

Figure 3-1 : Schematic model of Chicago patrol force allocation using " equal effectiveness" and " different effectiveness" conditions against Part I or " index crime." Allocations use weighted workloads but are not subjected to a mathematical optimization process. In the diagram x-x denotes " equal effectiveness" assignments; 0-0 denotes " different effectiveness" resulting from the ratio of felony arrests/manpower. The Part I crimes are weighted according to Selin and Wolfgang and normalized by present assignment and district population. Current allocations -□—□- are accurate for May of 1969.



enforcement component merely produces the arrests.

There is an intuitive, non-quantitative relationship between the threat of arrest (and subsequent punishment) and deterrence of crime. If that assumption is made, the ratio "arrests per man" is a crude measure of effectiveness.

Table 3-11 summarizes felony arrests per man assigned from each district. Also shown are total arrests per man. Arrest data is for the fourth police period 1969. Manpower assignments are those for May, 1969.

Other Measures of Effectiveness

Chapter 5 discusses mathematical methods to improve the efficiency of preventive patrol assignments. These methods involve determination of geographical location of crime throughout an area, followed by a scheme for working the crime cluster so identified to maximize the benefit from assignment of manpower is maximized.

Clustering and mathematical allocation into the various cells in the city provide dynamic methods for periodically revising the external of K in a district. This potential represents an important direction for continual analytical and practical wokr for an allocation scheme, locally or city-wide, based on the consideration and is amenable to the same type of administrative experiment as was carried out in the 14th District.

New Manpower and Effectiveness

The allocation scheme that embodies all of the factors except geographical area is the one that is based on the minimization criterion of Shoup-Dosser with the component index crimes weighted by the technique of Selin-Wolfgang and normalized by district population. It is always necessary to divide the crime in the district by current manpower assignment.

In the following tables, two additional effects are shown. The first concerns the effect on the allocation if effectiveness is (a) considered equal throughout the City, and (b) considered proportional to the ratio of felony amounts to manpower assigned. Table 3-10 shows the result for the basic patrol division of 6,708 men.

Tables 3-12, 13 and 14 show how additional patrol resources might be allocated. For these illustrations, total patrol resources of 7182, 7769, and 9188 are examined. The reason for these choices is to show how the objectives of efficient allocation of resources throughout the city might be established as criteria against which actual police activity can be measured.

Evaluating Street Activity

The choice of these numbers of the augmented patrol force is not accidental. Certain resources of police divisions in Chicago, and in other cities, are assigned on a police area basis. These other resources are often used as street activity resources. Usually, however, they have specialized mission assignments. The preceding tables, in fact, show the allocation among districts of a patrol force reinforced by components of Chicago's other police administrative divisions. Such a reinforced patrol can be formed in the following ways:

9188—All street resources including Bureau of Field Services' patrol, detective task force, traffic and youth divisions. (Table 3-14).

7769—Patrol force plus detective force (Table 3-13).

7182—Patrol plus detective task force (Table 3-12).

A schematic representation of the effect of using the present 6,708-man force under conditions of "equal efficiency" and "different efficiency" (the ratio of felony arrests to manpower) is shown in Figure 3-1 along with current manpower allocations.

REFERENCES

1 Ivan Selin and Marvin E. Wolfgang, *The Measurement of Delinquency*, New York, Wiley, 1964.

2 Carl S. Shoup, "Standards for Distributing a Free Governmental Service: Crime Prevention," *Public Finance*, Vol. 19, No. 4, 1964.

3 Douglas Dosser's notes on Shoup., *ibid.*

CHAPTER 4

*THE POLICE RESPONSE FUNCTION**

Response to citizen demands for service is the most visible output of the Chicago Police Department. Over the past decade, Chicago police administrators have put strong emphasis on rapid response to any citizen request. The stated objective is that any citizen should expect response within about five minutes—depending, of course, on the degree of emergency that the request implies. Except at peak periods, this objective was very nearly being met in 1969, although demands for police service have doubled since the objective was announced.

This chapter reviews the major results obtained from analyses of the response function. The overall purpose of the analysis is to improve the efficiency and capacity of the Chicago police force to carry out the response function. The importance of this portion of the activities of the Chicago Police Department is attested by the fact that some 6,700 men of the Patrol Division devote nearly full time to handling response to calls for service. The urgency of the problem of improving capacity is shown by the yearly increase in calls for service to which beat cars are dispatched. The current rate of increase is 8 to 10 percent per year.

Unless corrective measures are taken, there is immediate prospect that the Communications Center will be saturated, the street response units overloaded, and as a result, timely response to emergency situations—crime in progress, officer needs assistance, etc.—would be impossible. Even in 1969, police districts found themselves with no response units available during periods of peak demand. These are potentially very dangerous intervals of time for all citizens.

The material in the chapter discusses the response function in general as it relates to this overall objective of the Police Department and defines the resource allocation problems that exist in planning for the response function including measures of effectiveness. From these are derived the conclusions and recommendations for immediate and longer term action. Technical details of the analyses and computer simulations appear in a separate section at the end of this chapter.

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Allocation for the Response Function

The level of public demand for police service is a factor that is, in general, not under the control of the police department. All matters that possibly involve enforcement of the law or protection of life and property must receive prompt response. In addition, since the police are representatives of city government available on an around-the-clock basis, police service is often requested for matters in which the citizen actually wants service from another public agency. Depending upon the policy of elected government and of the people they represent, the level to which the police should attempt to render general public service is subject to modification by police and public administrators.

In Chicago, in the summer of 1969, the policy was to respond to all citizen calls when the presence of an officer can render service or assistance. Citizen calls for service that are misdirected to the police are referred to appropriate city agencies. Examples of such calls include complaints about trash collection, in which the caller is referred to the Department of Streets and Sanitation, or requests for information on driver's licenses, in which the caller is referred to the Office of the Secretary of State of the State of Illinois. About 35 percent of all incoming calls are referred to other state or municipal agencies.

Even with this initial screening, beat cars are dispatched on about 8,000 calls per day. Nearly half of these occur during the period 1800–0200 hours. Of these 8000 calls per day, 74 percent do not specifically involve law enforcement, although some do involve emergency service or situations that could readily deteriorate to an enforcement problem. Only about

12–15 percent of all calls for service to which units are dispatched involve criminal law enforcement.

The discussions in this chapter deal with this situation and with ways to improve the capability of the Chicago Police Department to handle the response function. The assumption is made that response is a function that cannot be delegated to any other agency; however it may be amenable to some administrative or policy adjustment. This response function, as conceptualized by the term "response force", contributes importantly to three of the principal objectives of the police department outlined in Chapter 1:

1. Protection of life and property. Maintenance of peace and order.
2. Public service.
3. Community support.

The third objective, community support, is affected by the quality of the service and is difficult to measure in any quantitative manner.

Response initially involves the activity of the Communications Center which receives the call, identifies the problem and the location, and assigns a response unit. This step is called the *Communications Center response*. The second part of the process is receipt of the assignment and travel to the point at which service is to be rendered by the response unit in the field. This is called *field response*. Both processes are analyzed in detail.

Effectiveness for the Response Force

Systems analysis of the police department has identified police-community goals as the minimization of crime disutility—the impact of crime—on an individual in the city. One direct way of reaching the goal is by the arrest of a criminal offender. The presumption is that arrest will be followed by swift prosecution and the levying of some punishment. When swift and sure justice follows arrest, the threat of arrest itself can act as a deterrent to crime.

There is considerable evidence that probability of arrest is directly proportional to the immediacy of response. Consequently, one important measure of effectiveness is *elapsed time*, the time from the occurrence of the criminal event until the response unit arrives.

This elapsed time is, in turn, influenced by the Communications Center response time, the geographical distribution of the units in the district at the time of occurrence of the crime, and the availability of the response units. Geographical distribution affects travel time. The term *availability* refers to the response unit being uncommitted to any activity, and thus able to accept the assignment. Most suggestions that result from these analyses have the objective of increasing *availability*.

The number of response units assigned during any watch is fixed. The probability that a unit will be able to accept an assignment without delay, the *availability*, is strongly affected by the level of demand for police service (calls/hour) and the total time that is required to complete the service. This last factor is called the *service time*.

Service time is affected by the nature of the demands for service, the distribution of various types of service in a district, and by factors such as unit aggressiveness, motivation, and individual initiative. An important constraint on service time is the necessity to maintain professional standards of excellence in rendering the service.

Other measures of effectiveness of the response units are those involving quality of the police service, thoroughness of preparation of the case for follow-up when arrest does not follow directly from the response, and similar qualitative factors.

In the Communications Center, there are a number of potential measures of effectiveness that describe various aspects and attributes of the operation. Analogous to availability of response units is radio channel availability, measured by the percentage of time radio channels are in use because of talk-out or call-in from response units.

There are other features in the Communications Center that relate to the rapidity with which an incoming telephone call is answered. Prompt answers are insured by furnishing a cascade of overload desks. The magnitude of incoming call delays that may be experienced in peak periods can be changed by varying the number of answering positions at the console or overload positions.

These partial measures of effectiveness for both the Communications Center and the field response force are combined through the logic of mathematical analyses to design the response force and to estimate its ability to handle demand under a number of different conditions.

Use of the techniques of computer simulation resulted in two major models. The first is a detailed simulation of the Communications Center as it is presently configured. The second is a simulation of the field response force assigned to the 14th Police District plus that of each police district contiguous to Dist. 14. In effect, this second model covers most of the north side of Chicago.

The purpose of the analyses was to ascertain which administrative, procedural, or equipment changes and improvements could most significantly effect the response function. A second purpose was to provide analytical and computer techniques for determining the number of response units needed, based upon the level of demand for service. An objective in improving the methods for estimating the temporal distribution of patrol resources to the response function is to increase the amount of resource that could be released for preventive patrol function. Close design of the response force also permits modification of the temporal distribution of preventive patrol activity. This is an important consideration since the heavy workloads of district law enforcement personnel, the motorized beats, virtually preclude carrying out mission-oriented preventive patrol at the time of greatest liklihood that criminal events will occur.

Analysis of the Communications Center

In spite of the fact that the Communications Center is now handling more than twice the volume of calls for which it was designed, the present configuration and procedures regarding manning of auxiliary positions are very efficient. The modal value for Communication Center response time is about 90 seconds. The mean or average Communication Center response time is found to be about three minutes, as measured by response to robbery complaints in the 2nd District. In that same robbery study, the total police response had a modal value of four minutes and an average of about nine minutes.

Of various alternatives in manning auxiliary positions, the maximum attainable reduction in Communications Center response time was about forty seconds. To obtain this small reduction in the overall response time, additional personnel would be required in the Communications Center.

The inherent operational problems of the Communications Center make it necessary to consider difficulties posed by future growth. The continuing increase in demands for service and related radio communications is inevitable. Increased use of the available radio frequency spectrum must accompany the wider use of personal police radios, the assignment of frequencies for emergency and command broadcasts, and the possible introduction of teleprinters in mobile units.

At present, in certain radio zones, a severe lack of air time has been noted. The effect is to force the caller or the street unit to wait. At peak times, more than one call on radio communication may have to wait. This results in the formation of a queue and causes delay in response. These communications queues are in direct result of low availability or its complement high utilization. Explicitly, the basic questions are the following:

Is the Communications Center (CC) functioning efficiently given its design, both on the input and output side?

How should projected growth in inputs and outputs be accomodated (the growth-problem)?

As previously stated, a simulation model was developed to analyze the efficiency of the processing of telephone calls by the CC. The primary results: The CC is very efficient on the input side, but significant improvement on the output side cannot be made with the current design of the CC except by increasing the capacity or lowering the activity level through screening and stacking. At most, an average of forty seconds can be shaved off based on the current design.

Addressing the second question, the problem is to accomodate anticipated growth in calls to the Communications Center to which a unit is dispatched. These calls are increasing at the rate of 8 to 10 percent per year.

Alternatives to be evaluated are:

1. Maintain present CC design and capacity.
2. Maintain present CC design and increase the capacity.
3. Change design to a conveyor type system or a car locator-computer dispatch system.

An important point is that these alternatives have to be evaluated with respect to the effectiveness of the total response system, not the CC subsystem alone. There are important tradeoffs between the CC subsystem and Field Response subsystem.

The first question raised can be answered immediately. Assume that (1) calls for service will continue to increase at the rate of 10 percent per year; (2) the daily profile of calls will remain unchanged, and (3) administrative and assist calls will remain in the ratio of 1.33 to calls for service.* Using the base case of 8,000 calls for service per day received during the summer of 1969, a queuing analysis application permits determination of the loadings (utilization) of various alternatives. It is sufficient to conduct analysis of radio transmissions without considering telephone call input as a transmission bottleneck.

*For every 100 responses to calls for service, there are 133 other incidents the effects of which is to remove the units from availability status.

Table 4–1

Forecast of Calls for Service

Year	Total calls	Daily peak per hr. (CFS + admin.)	Loading, w/8 channels	Channels for .5 loading	Channels for .4 loading
1969	8,000	1,285	.55	8	10
1972	10,600	1,707	.73	12	15
1974	12,800	2,064	.89	14	18

Total calls are predicted and the peak hourly input can be determined from the profile of daily calls. It is then possible to estimate loading on a facility having eight channels to handle the transmissions.

Police administrators consider a loading of more than 50 percent as undesirable. Great emphasis is placed on short delay time before a channel is available for use.

The configuration and capacity of the present system cannot cope with the anticipated increased demands.

The number of consoles necessary for a 50 percent and 40 percent loading level is calculated in the last two columns. A substantial increase in the number of consoles will be needed.

Evaluation of the relative costs and benefits of the last two alternatives has not been undertaken since it would first be necessary to model field response activities so that response system characteristics could be evaluated.

Analysis of Street Response

The effectiveness of response units is dependent upon the operational procedures that place the manpower where it is needed when it is needed. This "where-when" concept is articulated in law enforcement literature as "space-time." This recognized jargon is adopted here and in the following chapter.

The factors that influence effectiveness of the response force (units assigned to the response functions) are the following:

Demands for service in space/time.
Positioning of forces in space/time.
Assignment rules.
Organizational variables (such as supervision, screening and stocking policies, interdistrict dispatching, etc.).

The method that is used now (1969) for allocation of resources of the patrol division is based on the twin objectives of equalizing the response workloads in areas of the city and providing duty time for carrying out preventive patrol. A further objective is to allocate patrol division resources so that 50 percent of this effort is devoted to the response function and 50 percent is devoted to the preventive patrol function.

Under current practice, the equalization of workload is accomplished by the assignment of respective weights of 4, 3 and 1 to service calls in categories of Part I crimes, misdemeanors, and general public services. The semi-annual geographic assignment of manpower is based on experience during the same seasonal period the previous year; i.e., Summer 1968 defines allocation for Summer 1969. A further assumption is made that the average call for service takes about sixty minutes. Boundaries of motorized beats are drawn so that peak period (third watch) workloads are equalized and sufficient units are assigned to establish an availability of .5 on the average.

In concept, the allocation procedure can be faulted only by questioning the criterion that street resources of a police department should be equally engaged in response and preventive patrol functions. This questions the hypothesis that the response function and the preventive patrol function are equally effective in achieving city-wide minimization of crime.

The Operations Research Task Force was unable to substantiate any quantitative assertions about the relative proportions of patrol effort that should go to response or preventive patrol. At this stage in the development of knowledge about the process of law enforcement, the question of emphasis must be decided based on such comparative analysis and confirming experiments in the future. In terms of the objective of lowering crime to irreducible minimums, there are no quantitative estimates of the relative contributions expected from the response or the preventive function.

In 1968 and 1969, the overall activities of units comprising street resources have been such as to make distinctions between response effort and the effort devoted to preventive patrol of little importance. With increasing frequency, as the service demand rises, availability of units for response assignments decreases. This fact is documented in the "exceptions" report that is prepared for command levels in the Chicago Police Department by the Commander of the Communications Section. This report indicates time intervals on each watch when *no* units are available for response to calls for service in various police districts. When emergencies occur in a district having no units available, response units from adjacent districts are assigned.

Such situations are characterized by above average response times.

With regard to the present allocation policy, it is germane to note that:

(A) The weightings 4-3-1 used bear no relation to the service time expended in 1969 on the Part I, Part II, and miscellaneous service calls.

(B) The city-wide motorized beat structure that results from the weighted workload-based design does not reflect the annual trend in calls for service that has been increasing at the rate of 8–10 percent per year.

(C) The beat structure ignores heavy fluctuations in calls for service which overload the capabilities of the motorized beats; this makes the concept of equal distribution of response and preventive patrol meaningless.

(D) The goal of preventive patrol is handicapped by duty time consumed by patrol units in routine administrative tasks and in giving assists to other patrol units; Routine administrative tasks consume about two hours per unit per watch. (The number of cards indicating "down" status for administrative tasks nearly equals the cards on file for police response to calls for service—nearly 6,000 per day.)

Assigned "assist" activities occur in 10–20 percent of all response activity. There is no doubt that the "assist" activity, whether assigned or spontaneous, has the twin effects of removing units from an availability status and causing occasional geographic concentration and rarifaction of response units.

FORECASTING SERVICE DEMAND

Demands for police service in Chicago as well as in other large cities are predictable. In each geographical area of Chicago, strong correlation is observed between levels of activity in any given week of the year with the activity one year ago, two years ago, etc. Comparisons among different weeks is facilitated through the use of the police year of thirteen four-week periods. This device eliminates irregularities in monthly comparisons caused by variation in the number of weekends.

This seasonal correlation and a similar repeated ratio between weekday and weekend activity has made it possible to forecast demand for service using merely the level last year and the observed upward trend. Agreements with reality have been within 5 percent.

A more sophisticated forecasting technique has been used with success by the St. Louis Police Department. Since the exponential smoothing technique, as the mathematical method is called, does take in and weigh all of the observed time dependent factors, it is the preferred method. The exponential smoothing technique will allow confident forecasts of activity levels by hour of the day. Details can be found in the technical section.

The OR Task Force is awaiting the results of contractural work that will modify an exponential-smoothing computer program proprietary to the Control Data Corporation. Each week an hourly forecast for the ensuing four weeks will be prepared and that forecast will be coupled into a queuing model to suggest a range of unit assignment loads geared to observed variability in the forecast. Once the modification is made, the forecast to support assignment of response units in all 21 districts of the City of Chicago can be made weekly for a very moderate cost. The documented program and supplemental material will be forwarded to the U. S. Department of Justice since it should be of value to other law enforcement agencies.

Due to the non-availability of the desired forecasting techniques, linear prediction was used to demonstrate the method and to provide a basis for the administrative experiment that was conducted in the 14th District.

From the forecast, it is possible to estimate the hourly rate of arrival of calls for service. This is input for the mathematical model for estimating the number of response units required that has been referred to in the queuing model. This statistic is also an input to the simulation model of the response force.

DESIGN OF THE RESPONSE FORCE

As with the attempt to forecast, parallel analytical methods were developed for the design of the response force, i.e., the determination of the number of units needed as a function of time and activity. The analytical approach was the application of queuing theory. The computer simulation of the response force is an alternative method which does not require the restrictive assumptions regarding the mathematical form of the distribution of arrival rates and service times.

The chief virtue of the analytical model based on queuing theory is simplicity. This results from the simplifying assumptions concerning the statistical form of parameters related to level of activity and service times. Although the assumptions are reasonably accurate, an examination of the data does show some significant departures from the assumed form. Nevertheless, use of the queuing model under the assumption that calls for service follow a poisson distribution and that the service is negative,—exponentially distributed, yields a simple graph that can be used to estimate force requirements. Future analytical work will probably show that the data support the use of some type of Erlang distribution.

The simulation model does not require any assumption concerning the form of the input or output distributions. It used the actual observed distributions. This is a distinct advantage, particularly when it is required to evaluate a new procedure prior to actual field test. The results of the hand graphical method for designing the response force follow:

Figure 4-1 is a plot of solutions to the queuing

Figure 4-1 : Estimating the number of patrol cars required to handle a known rate of incoming calls for service is possible with this plot derived from queuing equations. The rate of calls is carried across to the appropriate line for the mean time needed to complete a service request ; dropping down from the point of intersection yields an estimate of the number of patrol cars needed to limit waiting for an available car to .10 minutes or six seconds.

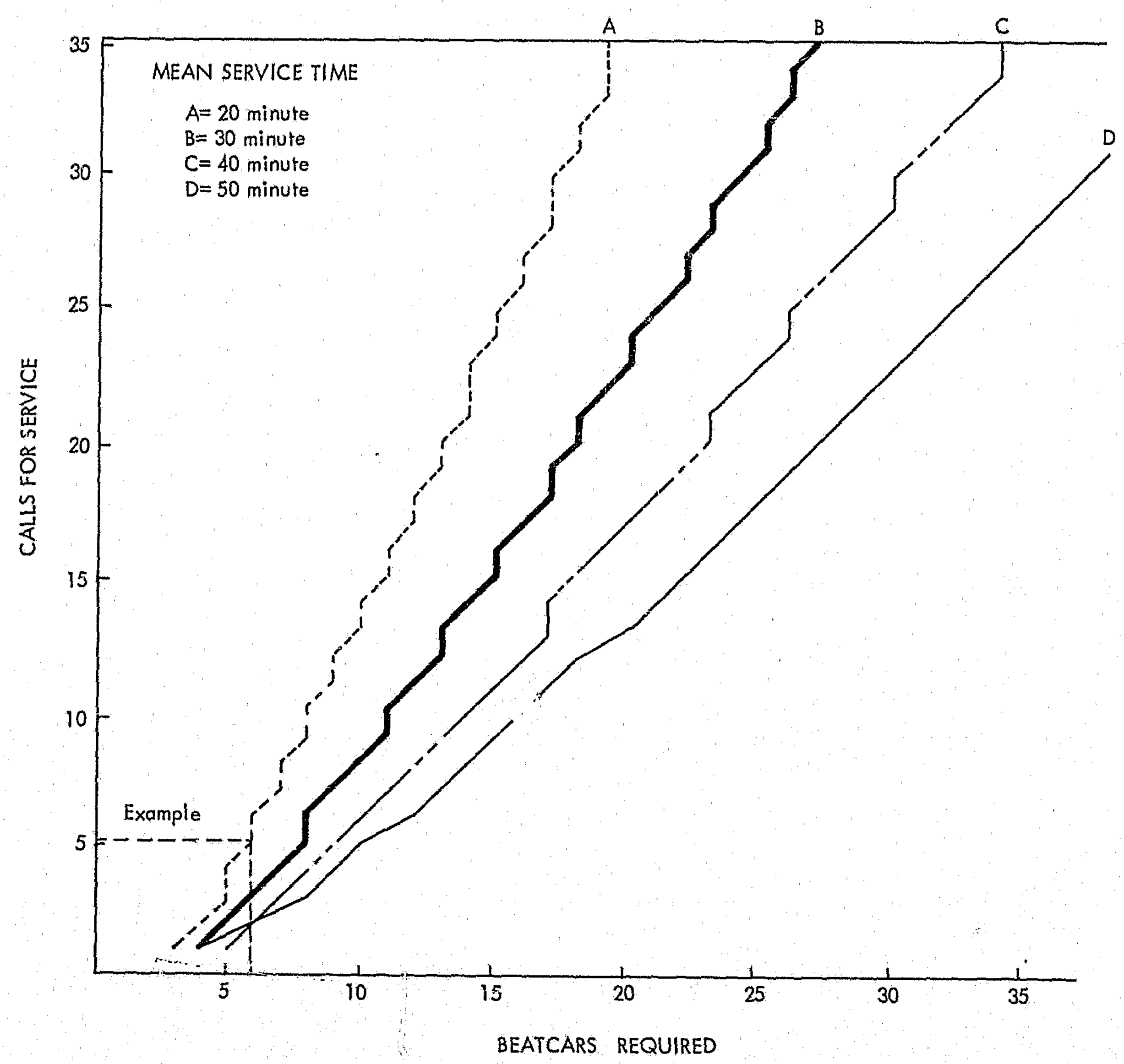


Table 4–2

Hourly Rates of CFS Projected for August, 1969 (Friday)

Hour/District	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	5.8	18	15.7	8	7.9	8.2	11.7	8.4	9.9	11.5	13.1	7.7	10.3	8.4	9.4	4.5	5.3	12.9	12.5	16.4	10.0
2	4.5	15	13.1	7	7.3	5.3	10.2	5.7	7.4	9.4	11.2	6.6	8.3	6.1	9.2	3.4	4.3	9.4	8.8	12.6	9.0
3	4.0	12.6	9.6	5.3	5.9	5.25	7.8	3.9	6.6	6.5	8.0	4.9	6.9	5.5	6.3	2.7	3.0	8.3	7.2	10.0	6.9
4	2.7	9.2	6.7	3.18	4.2	2.9	5.4	2.4	3.3	5.0	6.6	3.6	5.4	3.9	3.7	2.2	1.9	6.9	5.9	6.8	5.6
5	2.7	7.3	5.5	2.5	4.1	3.2	4.4	1.8	3.3	4.0	4.4	2.0	3.4	3.4	3.0	1.0	1.9	5.9	2.9	5.5	3.8
6	2.1	5.9	5.3	1.9	3.4	2.1	2.8	1.4	3.0	3.0	3.9	2.6	2.4	2.2	3.0	1.2	1.6	4.4	5.0	4.5	3.3
7	3.2	4.6	5.4	2.7	4.9	3.1	3.5	2.6	3.5	4.3	5.4	3.1	4.2	4.1	4.6	2.4	3.1	4.2	8.0	6.8	2.6
8	3.8	6.6	6.5	4.9	4.2	4.2	4.8	5.6	5.7	5.4	6.4	5.0	5.7	5.6	7.8	4.0	4.3	6.5	8.6	10.4	4.1
9	6.7	8.4	7.2	5.3	7.3	6.4	6.5	5.8	6.5	6.7	7.7	6.4	7.9	7.1	9.2	4.7	5.8	7.7	11.4	12.4	7.3
10	8.1	11.7	9.3	7.8	9.4	7.4	8.2	7.6	8.9	9.4	9.5	7.7	9.3	10.0	9.8	5.8	6.3	10.7	11.1	15.8	8.8
11	8.2	13.1	9.0	7.1	7.4	6.6	10.7	8.4	9.6	10.9	11.0	9.1	9.9	10.0	9.6	5.4	7.4	11.3	11.4	15.2	8.8
12	9.8	14.4	10.9	6.7	7.6	6.7	11	7.7	9.8	11.3	11.4	8.9	10.5	10.0	10.4	6.3	7.8	12.7	11.2	14.3	8.8
13	10.4	16.4	12.7	8.5	9.0	6.7	12.5	8.7	9.5	13.2	13.5	9.2	11.5	10.5	11.0	6.7	7.8	12.5	11.2	13.9	10.4
14	9.3	16.4	13.5	8.5	9.2	8.2	14	8.4	11.0	12.9	13.3	10.3	12.7	10.5	12.4	6.1	7.8	13.6	11.3	16.8	10.6
15	10.9	16.8	12.7	9.2	9.8	7.3	14	9.0	10.5	12.9	14.4	10.1	13.2	11.6	11.5	6.7	6.6	13.9	12.0	15.3	10.6
16	12.6	19	14.6	10.4	10.7	8.8	16.6	10.7	13.0	15.4	15.7	11.4	14.6	13.5	13.6	6.9	7.8	16.0	12.8	19.5	12.5
17	13.8	20.4	15.7	12	12.1	9.9	17.3	12.2	15.0	16.2	17.5	14	12.6	16.5	16.7	9.3	10.7	15.6	15.8	20.0	14.8
18	13.2	22.2	19.0	11.7	13.2	11.1	18.3	13.0	14.0	17.2	19.0	12.9	19.8	18.2	17.8	9.7	10.2	18.5	18.1	22.9	15.6
19	10.0	26	20	12.7	13.8	11.8	19.8	13.9	17.0	19.4	20.3	13.0	20.8	18.3	17.3	8.4	10.0	18.5	19.1	22.2	14.5
20	8.4	25.2	20	12.9	14.3	13.4	21.2	13.4	15.6	19.4	20.6	12.7	20.3	18.7	15.9	10.9	11.3	16.8	19.8	23.6	14.8
21	7.9	28	20.4	12.5	16.3	13.4	24.2	15.5	17.7	21.4	22.0	13.3	18.7	19.6	16.6	9.9	10.5	17.0	20.0	25.2	16.1
22	7.3	29	22.6	15	15.9	12.8	22.9	15.9	19.1	22.6	21.6	12.6	21.4	19.7	17.5	8.8	10.7	17.7	21.8	27.2	17.0
23	6.8	28.4	21.0	15.2	15	12.9	21.7	15.9	20.8	23.4	21.2	12.9	20.0	20.5	17.5	9.2	10.1	21.0	22.0	28.7	14.8
24	6.0	25.5	20.8	13.1	13.1	11.8	20	13.8	17.1	20.0	20.8	12.6	12.4	16.0	14.0	8.3	8.5	18.3	20.4	27.2	14.5

Table 4–3

Patrol Units Available on a Typical Summer Friday, 1969

Area	District	First watch							Second watch							Third watch						
		Lt.	Beat	Sgt.	Unit	Sqdl	Vice	Tot.	Lt.	Beat	Sgt.	Unit	Sqdl	Vice	Tot.	Lt.	Beat	Sgt.	Unit	Sqdl	Vice	Tot.
I	1	1	9	2	3	0	0	3	1	14	2	0	0	1	3	1	11	2	3	0	1	2
	2	1	13	3	3	5	2		1	28	4	3	5	2	3	1	20	4	3	5	2	2
	21	1	23	2	1	3	1	0	1	24	2	1	3	1	4	1	30	4	2	3	1	4
II	3	1	15	3	3	3	0	0	4	23	5	4	5	1	0	4	23	5	3	4	1	3
	4	1	15	2	0	3	0	0	1	16	3	2	3	1	3	1	16	2	2	3	0	3
	5	1	12	0	0	3	0	0	1	20	3	0	3	1	4	1	20	2	0	3	0	2
	6	1	15	2	1	2	0	0	1	17	2	1	2	1	0	1	18	2	1	2	1	4
III	7	1	14	2	4	4	1	2	1	23	2	7	4	1	3	1	26	5	7	4	1	4
	8	1	20	3	0	2	0	0	1	19	3	1	2	1	2	1	20	2	2	3	1	2
	9	1	13	2	0	3	0	0	1	17	2	0	3	1	1	1	20	4	0	3	1	0
IV	10	1	13	2	0	3	0	0	1	24	4	2	3	1	7	1	24	4	1	3	1	6
	11	1	14	4	0	4	0	0	1	25	1	1	3	2	4	1	25	4	2	4	2	5
	12	1	11	2	2	3	0	0	1	15	2	2	4	1	1	1	15	2	2	4	1	0
	13	1	13	2	1	3	0	0	1	19	4	1	3	1	1	1	24	3	0	3	1	1
V	14	1	19	3	0	3	0	0	1	17	3	0	3	1	4	1	20	4	0	3	1	2
	15	1	11	2	1	3	0	0	1	18	3	1	3	1	4	1	19	3	1	3	0	5
	16	1	10	3	0	2	0	0	1	11	3	0	2	1	1	1	11	3	0	2	2	2
	17	1	10	2	0	2	0	0	1	12	2	0	2	1	2	1	12	2	0	1	1	2
	18	1	15	2	1	5	0	0	1	22	4	0	5	0	2	1	22	3	2	5	0	3
	19	1	16	2	0	3	0	0	1	23	3	0	3	1	4	1	26	3	0	3	1	2
	20	1	17	3	0	4	0	0	1	24	3	0	4	1	6	1	28	3	0	4	1	5

Table 4–4

Mean Service Times by District and Watch (Minutes)

[Data taken from August 1968]

District	First watch	Second watch	Third watch
1	15	55	31
2	44	22	33
3	32	48	33
4	32	33	15
5	23	53	36
6	30	32	35
7	30	36	39
8	26	29	26
9	25	33	27
10	35	45	41
11	33	44	36
12	32	35	35
13	20	31	38
14	21	30	34
15	14	27	29
16	23	38	28
17	21	42	34
18	30	41	41
19	16	29	30
20	18	33	30
21	29	39	36

equations described later in the technical discussion. However, when the hourly rate of arrival for calls is known, along with the mean service time for the appropriate time of the day, one can enter the graph and read the number of beat cars required from the horizontal axis.

Table 4-2 projects the hourly rate of calls for service in each police district projected for Friday. Friday is generally the busiest day of the police week. Table 4-3 shows Summer 1969 manning for each watch.

Table 4-4 shows the mean service time by district and by watch as derived from rough data from a period in August 1968. Again, the assumption is made that the characteristics of the calls for service in 1968 and the service times were similar in 1969.

Table 4-5 shows the number of units required under a "no wait" policy. Additional units would be needed for special details and to handle administrative assignments.

Table 4-6 shows the district manning for Third watch, summer 1969, compared with the projected response unit requirements at times of peak activity. There is little margin of safety yet the actual assignment is supposed to reflect provision of approximately 50 percent of the assigned time for aggressive preventive patrol. Clearly such activity can occur only at off-peak hours and is in competition with administrative and personal assignments. Examination of administrative records for a period in August 1968 revealed that the average beat car spends 1.9 hours *per watch* on administrative assignment.

The seriousness of the situation is confirmed by the

Table 4–5

Cars Required To Handle Response Each Hour, Each District

Hour/District	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	6	21	15	10	7	10	13	10	11	16	13	10	8	8	8	5	6	13	10	12	11
2	6	18	13	9	7	8	11	8	9	13	12	9	8	6	8	5	5	11	8	10	10
3	5	16	11	8	6	8	10	7	9	10	10	8	7	6	7	5	5	10	7	8	9
4	5	12	9	7	5	7	8	5	7	9	9	7	6	5	5	4	4	9	6	7	9
5	5	11	8	6	5	7	7	5	7	8	7	5	5	5	5	3	4	8	5	6	7
6	4	10	8	6	5	5	7	5	7	7	7	6	5	4	5	3	5	7	6	5	7
7	5	9	8	6	5	6	6	6	7	8	8	7	5	5	6	4	5	7	7	7	7
8	5	11	13	8	10	7	9	8	8	9	9	8	6	8	7	8	10	11	11	11	8
9	13	7	15	8	13	8	10	8	9	10	12	11	10	9	11	9	10	12	12	13	11
10	14	9	15	10	15	9	12	9	11	13	13	13	11	11	11	10	11	14	12	15	13
11	14	10	17	9	14	9	15	10	11	15	15	15	11	11	11	9	12	15	12	15	13
12	16	10	20	9	14	9	15	10	11	16	15	16	12	11	11	10	12	16	12	14	13
13	15	11	21	10	15	9	16	10	12	17	16	17	13	11	12	11	12	16	12	13	15
14	16	11	20	10	15	10	17	10	12	17	16	17	13	11	13	10	11	17	12	16	15
15	20	13	21	11	16	9	17	11	13	19	19	17	14	13	13	11	12	18	13	15	15
16	16	18	15	9	16	11	20	12	15	19	21	19	14	13	13	10	10	19	13	18	16
17	13	19	17	9	17	11	21	13	14	20	22	21	17	15	16	11	11	19	15	18	17
18	13	22	18	10	17	12	21	13	16	22	22	22	18	17	17	11	11	22	17	20	19
19	10	21	18	10	17	13	22	13	15	22	23	22	18	17	17	13	12	22	18	21	17
20	10	23	18	10	19	13	23	15	17	23	25	22	18	17	15	14	11	20	18	21	17
21	9	23	19	11	19	13	26	15	17	24	23	24	17	18	17	13	11	21	19	22	19
22	9	23	18	11	18	13	25	15	18	23	23	24	19	18	17	13	11	23	20	23	20
23	8	21	18	10	17	13	23	15	17	22	22	23	18	18	14	13	10	22	18	23	18
24	8	21	18	10	17	13	23	15	17	22	22	23	18	18	14	13	10	22	18	23	18

Figure 4–2: Copy of Car Outage Report for 11 July 1969.

COMMUNICATIONS SECTION DATE 11, July 1969

TO: Commanding Officer, Communications Section

FROM: Lt. J. Fitzmaurice, Watch Commander, 3rd Watch

SUBJECT: No Cars Available - Excessive Lunch Period Report

NO CARS AVAILABLE

Dist.	Zone	Start	End	Notification	
007	7-only	1605	1623	none	
009	6-only	1619	1635	none	
XXX	XXXXXXX				
003	7-only	1747	1845	none	
018	2-total	1756	1829	Capt. Cloherty	
TA1	CW1	1551	1739	Sgt. Craft	
TA5	CW1	1626	1647	Lt. Redding	
007	7-only	1754	1920	none	
002	5-only	1847	1907	none	
018	2-total	1847	1851	Capt. Cloherty	W/C
012	4-total	1906	1918	Capt. Hines	W/C
021	5-only	2004	2011	none	
014	3-total	2008	2025	Lt. Polit	W/C
002	5-only	1919	2033	none	
002	8---	1949	2058	Capt. Fogarty	W/C
021	8-only	1946	2058	Capt. Vojtech	W/C
004	8-total	2003	2022	Lt. Walsh	W/C
011	4-total	2016	2107	Lt. McAvoy	W/C
020	1-total	2103	2118	Lt. Besso	W/C
021	5-only	2059	2127	none	
002	5-only	2109	2136	none	
018	2-total	2119	2208	Capt. Cloherty	W/C
002	8 only	2106	2220	none	
014	3	2232	2235	Lt. Pilet - W.C.	
009	5 only	2234	2237	none	
018	2	2244	2302	Lt. Murphy - W.C.	
004	8 only	2224	2316	none	
015	3	2202	2214	Capt. Russell, W.C.	

EXCESSIVE LUNCH PERIODS

Beat	Zone	Start	End	Notification
007	7 only		2225	none
007	7 only	2230	2239	none

Watch Commander, 3rd Watch

Figure 4–2
Copy of Car Outage Report for 11 July 1969.

detailed computer simulation of this present response force discussed in the technical section. In that analysis, actual data on administrative calls plus observed distributions were used. The conclusion that virtually the only preventive patrol that occurs is the effort contributed by the Patrol Division Task Force and the District Tactical Units is inescapable.

The analysis of the Task Force activity for a representative period in January 1969 shows the draw down that occurs on these assets during the course of a deployment due to arrest processing. This is presented in Chapter 6. Thus Table 4-6 suggests that from time to time there will be no cars available for service.

Table 4–6
District Manning for Third Watch, Summer 1969

District/ Forces	Units assigned 3d watch, summer 1969	Units required at peak	Units required at peak with 30 percent reduction
1	14	20	14
2	29	23	16
3	24	21	14
4	15	11	8
5	18	19	12
6	15	13	8
7	26	26	18
8	16	15	10
9	20	18	12
10	24	24	16
11	25	25	16
12	15	24	16
13	24	19	12
14	21	18	12
15	19	17	12
16	11	14	10
17	12	12	8
18	22	23	15
19	24	20	14
20	30	23	14
21	23	20	14

Figure 4-2 is a copy of the car outage report for the third watch, Friday, 11 July. It is introduced as corroborating evidence that the response system is nearing saturation under normal conditions.

Concept of the Basic Beat

Reference to Table 4-5 shows that at certain times of the day relatively few units are required. However, the necessity to be prepared to respond quickly to an emergency always exists. This condition is met in the proposed realignment of the beat structure into the five-minute basic beat. The phrase "five-minute" refers to the fact that the beats in each district are designed so that the maximum travel time under non-rush hour conditions would be five minutes. Since the beats are basically square, the expected travel time is a little over three minutes.

An example of the basic beats for the 14th District is presented in Chapter 6. Details of manning, as calls for service increase, are discussed there with respect to the pilot program in the 14th District. Suggestions are made for reducing the strain on the response force and increasing the effort devoted to preventive patrol.

Either the police facilities (men and Communication Center) have to be expanded to keep up with demands or the policy regarding response to calls for

Table 4–7
Cars Required To Handle Response Each Hour Each District If 30 Percent Reduction in Calls for Service Achieved

Hour/District	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	4	14	10	7	4	7	8	7	8	10	8	6	5	5	5	3	4	8	2	8	8
2	4	12	8	6	4	5	8	5	6	8	8	6	5	4	5	3	3	8	5	6	9
3	3	10	8	6	4	5	6	4	6	6	6	5	4	4	4	3	3	7	4	5	9
4	3	8	6	4	3	4	5	3	4	6	6	4	4	3	3	2	2	6	4	4	6
5	3	8	6	4	3	4	4	3	4	6	6	4	4	4	4	2	2	6	4	4	4
6	3	7	6	4	3	3	5	3	4	4	4	4	4	3	4	2	3	4	3	3	4
7	3	6	6	4	3	4	4	4	4	5	5	4	3	3	4	3	3	5	5	5	5
8	3	8	10	6	7	5	6	6	6	6	6	6	4	6	4	5	7	8	8	8	5
9	9	5	10	6	9	6	7	6	6	6	8	8	7	6	8	6	7	8	8	8	2
10	10	6	10	7	10	6	8	6	8	8	8	8	8	8	8	7	8	9	8	10	8
11	10	7	12	6	10	6	10	6	8	10	10	10	8	8	8	6	8	10	8	10	8
12	11	7	12	6	10	6	10	6	8	10	10	10	8	8	8	7	8	10	8	9	8
13	10	8	14	6	10	6	10	6	8	12	10	12	8	8	8	8	8	10	8	8	10
14	10	8	13	6	10	6	12	6	8	12	10	12	8	8	8	7	8	12	8	10	10
15	14	9	14	8	11	6	12	8	8	12	12	12	10	8	8	8	8	12	8	10	10
16	10	12	10	6	10	8	14	8	10	12	14	12	9	8	8	7	7	12	8	12	10
17	9	13	12	6	12	8	14	9	10	14	14	14	12	10	10	8	8	12	10	12	12
18	8	14	12	6	12	8	14	8	10	14	14	14	12	12	12	8	8	14	12	14	12
19	6	14	12	6	12	8	14	8	10	14	15	14	12	12	12	8	8	14	12	14	12
20	6	16	12	6	12	8	16	10	12	16	16	14	12	12	10	10	8	14	12	14	12
21	6	16	12	8	13	8	17	10	12	16	16	16	12	12	12	9	8	14	12	14	12
22	6	16	12	8	12	8	16	10	12	16	16	16	12	12	12	9	8	15	14	14	14
23	6	14	12	6	12	8	15	10	14	14	15	16	12	12	16	9	7	14	12	14	12
24	6	14	12	6	12	8	15	10	14	14	15	16	12	12	16	9	7	14	12	14	12

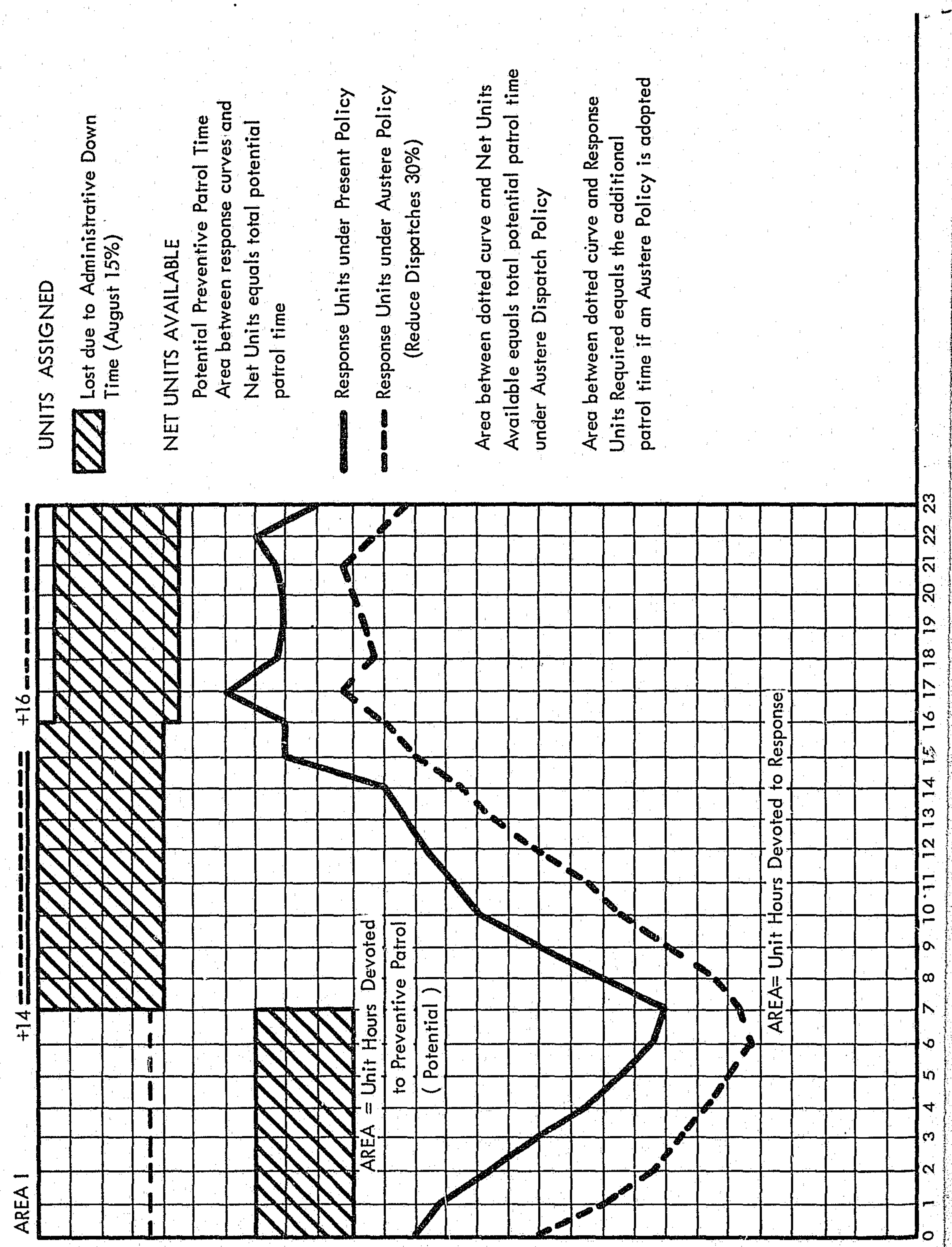


Figure 4-3 : Graphical Representation of Potential Value of Adopting an Austere Dispatch Policy.

service must be revised and a more austere policy inaugurated. Expansion of the police force and augmentation of the police communications system is a long lead time alternative. An austere policy can readily be established from the technical standpoint but great care is necessary in the preparation of the public to assure community cooperation. Figure 4-3 illustrates the potential for recovery of patrol time that an austere policy in regard to police service requests.

Detroit and St. Louis each have instituted controls over the type of calls on which units will be dispatched. In each city, citizens are asked to come into a police facility for purposes of filing routine reports. Also, there has been an increase in the referral of citizen problems that are of non-law enforcement nature to other city agencies. Community acceptance in both cities is reported as being good.

It appears possible to obtain about a 30 percent decrease in car dispatches through restriction by austere policies. Table 4-7 shows the anticipated numbers of units required for the response function if a 30 percent reduction in car dispatches for public service type activities can be achieved. The third column of Table 4-6 shows peak requirements that could reasonably be expected to be met with presently assigned available forces.

Reduction of 30 percent in car dispatches would be achieved primarily from the miscellaneous-other category of calls plus certain index crime category, such as theft, auto theft and perhaps some residential burglary. In these cases, it might be possible to defer the response until a time when demands for service were slack. Assuming a 6,000 call day, a reduction of 1,260 calls from the population of 4,200 non-law enforcement component calls would be the objective. On a City-wide basis this works out to be an average of about two calls per district per hour that would be deferred, referred, or for which the citizen would be asked to visit a police facility.

SIMULATING SEVEN DISTRICTS

A simulation model was developed for seven police districts on the north side. The seven districts include the 14th District and its contiguous districts. The objective was to create a laboratory where a car locator system and organizational variables could be compared under similar conditions.

This is a valuable approach. Computer simulation provides an alternative to administrative experiments, especially when these would be difficult or impossible to carry out. The model evaluates interdistrict dispatching and screening of calls with and without a car locator system. The following table shows the characteristics of the alternatives and the real world. Because of the shape of the response distribution curve, the modal value is a better characteristic for comparison than the average.

Assignment rules determine which car should be dispatched. The location of the call for service is known, however, without a car locator system car locations are unknown. The Chicago Police Department uses a center-of-mass dispatching strategy. If a car is available, it is assumed to be positioned at the center of his beat since no other information is available. Emergency assignments are transmitted on a separate frequency to all cars in the area.

Requirements would include evaluation of a car locator system where a nearest-car strategy could be used. As travel time is an important ingredient of response time, crossbeat travel should be minimized.

Conclusions and Recommendations

Availability of communications channels and of response units is the key to response force effectiveness. It is possible to increase the amount of effort that can be devoted to preventive patrol through close design of the response force.

A simulated high level of screening (33 percent of misc. non-criminal) and interdistrict dispatching provided a great reduction in the modal response time, and an increase in the availability of cars. The car locator system affects some improvement in the average value and variance.

The conclusion is that significant improvements in field response are possible through administrative policy changes. The car locator system, however,

Table 4-8
Response Unit Availability Under Different Conditions

	Mean	Standard Deviation	Mode	Availability of cars (percent)
Normal	8.5	10.3	3.0	35
Screening	5.92	6.98	3.0	45
Interdistrict dispatching	5.89	7.47	3.0	39
Car locator	4.82	3.73	3.0	35
Screening and interdistrict dispatching	4.53	4.37	2.0	48
Car locator system with screening and interdistrict dispatching	3.66	3.10	2.0	48

offers other advantages, *not* evaluated in this model, such as increased field supervision, and automatic car dispatching by computer.

It is recommended that the Response Force be deployed on the basis of design methods set forth herein, followed by use of the exponential forecasting method when results are available. This includes adoption of the basic beats (five-minute beats) on a City-wide basis. Implemental procedures should be those discussed in Chapter 6.

The most important immediate action that can be taken is to institute screening, referral, and deferral of non-emergency calls for police service. Such action will simultaneously ease the strain of excessive workloads and free resources for the preventive patrol function.

RESPONSE FUNCTION: TECHNICAL ANALYSIS

Chicago Communications Center

There are three different types of Communications Centers (CC). One is the old conveyor belt type in which calls are answered by a telephone operator, a card filled out and sent on a conveyor belt to the dispatchers. This system was introduced with the use of police radios over forty years ago. In fact, the Cleveland Police Department still had the original Communications Center in operation at the time of this study.

In 1961, Motorola designed a Communications Center for the Chicago Police Department. It remains representative of the state of the art; it will be described later.

The third type is represented by the SPRINT system being designed by IBM for the New York Police Department. It will include a car locator, computerized dispatching and teleprinters in cars.

Richard Larson[1] modeled the first type of system using data from the Boston Police Department. Surkis, et al, have developed a simulation model of the New York Police Department Communication Center using GPSS[2]. Rath and Braun[3] presented an initial systems analysis and the structure of a Simscript model for the Chicago Police Department Communications Center.

The Communications Center of the Chicago Police Department is a facility for processing information. Information inputs include demands for service and information requests from citizens and policemen. Outputs consist of car assignments and information. When a Citizen dials PO 5-1313, the call is automatically routed to a console which handles the area covered by the telephone exchange through which the call was received. There are approximately 60 telephone exchanges in the city. Each console is staffed by one or more console operators who answer calls and by a dispatcher who assigns police units.

In addition to answering calls, one of the console operators, in charge of the computer on-line inquiry unit processes, handles field inquiries about stolen cars and persons wanted on warrants. The console operators can also query the "hot desk." This is a facility in a separate room providing 24-hour access to files on missing persons and information stored in Springfield, Illinois, and in national files.

The dispatcher is in charge of radio communications with beat cars in the area assigned to his console. He receives requests for and transmits information, assigns cars, and maintains a status map of car availability. Car status is indicated on a beat map of the relevant area. Each beat has a small light on the console which, when illuminated, indicates the car is available for assignment.

There are seven telephone lines from the exchange to the console. When the call reaches the Communications Center, a timer is actuated. If the console has not answered the call within 12 seconds, an overload facility is actuated. The incoming call can now be answered at either the console or the overload facility. The overload facility consists of seven desks which can monitor all 56 incoming telephone lines. Eight consoles have seven lines each. The overload operator takes the call and fills out an IBM card. If the call is high-priority, the overload operator takes it to the correct console for dispatching; otherwise he actuates a yellow light requesting a messenger to relay the card. If the incoming call has not been answered within 30 seconds, the call is permitted to ring at the auxiliary desk, which has four operators. The call is handled there the same way as at the overload desks.

The different zones (exchanges) generate approximately the same number of calls. The ratios among console, overload and auxiliary is approximately 50:35:15. (Table 4-9) Distribution of calls during the 24-hour period is about 0001–0800 (15%), 0800–1600 (35%), and 1600–2400 (50%). The volume of incoming calls varies between seasons, lower in winter than in summer.

When calls are received relating to traffic accidents or vice, they are delivered to the Traffic Division console or the Vice Control desk. In addition to the above functions, the Communications Center has

Table 4–9

Answering Statistics for Communications Center

[For 13th Period, 5 December 1968–1 January 1969]

Zones	Total No. of calls	Under 12	Percentage	To 12–30	Percentage	Over 30	Percentage
1	30,360	10,461	34.44	14,048	46.26	5,851	19.26
2	29,963	12,234	40.82	12,809	42.74	4,920	16.41
3	25,222	17,986	71.29	4,887	19.37	2,349	09.31
4	24,858	13,961	56.15	9,262	37.25	1,635	06.57
5	24,223	14,657	60.50	7,156	29.53	2,410	09.94
6	28,314	16,023	56.57	9,219	32.55	3,072	10.84
7	29,856	15,298	51.23	11,457	38.36	3,101	10.38
8	25,488	13,383	52.50	9,444	37.04	2,661	10.43
Zones	**Grand total**	**Under 12**	**Percentage**	**To 12–30**	**Percentage**	**Over 30**	**Percentage**
1 through 8	218,284	114,003	52.21	78,282	35.85	25,999	11.90

desks for maintaining radio communications with the Preventive Force. If a call is of an emergency nature, such as a crime-in-progress or a policeman in need of help, the dispatchers can send out a call to all cars on a city-wide frequency.

Interesting statistics abound. For example, during 1968 3,261,738 calls were answered. Total calls to which a car was dispatched amounted to 1,942,599. In addition, there were 1,723,597 administrative and miscellaneous calls handled. All in all, 837,943 inquiries were made on the on-line, real-time computer inquiry system.

During the Fourth of July, 1969, over 15,000 calls were answered, about half of them between four p.m. and midnight. A normal summer day generates approximately 10,000 calls.

ELEMENTS OF THE PROBLEM

The Communications Center represents a complex system, as is evident from its description. It is difficult to convey the magnitude of this complexity. An enormous amount of short transactions of many different types are continuously in process. The problem can be stated:

1. What is the present response time distribution?
2. Is the system operating efficiently?
3. Can performance be improved by changing the use of resources?
4. Is a completely new system necessary?

Proposed changes include:

1. The assignment of manpower to consoles and overload positions.
2. Handling of computer inquiry at a separate facility.
3. Increasing the number of trunk lines incoming.
4. Changing the step-up intervals for letting calls ring at the overload and auxiliary desks.

The model structure and complexity are determined by the system being modeled and the output desired. The previous section identified some of the questions that the model should be able to answer. In addition to the response time distribution, it is necessary to know the average time to process a call and the percentage of calls answered at the three different levels respectively. Operational data of interest include:

Airtime per console.
Operator working time.
Dispatcher working time.
Overload and auxiliary operators' working time.
Size of different queues within the system.

The modeling technique chosen was simulation. Simulation was used because the physical structure of the Communications Center made it difficult to apply queuing theory, and the necessary distributions were not well-behaved, as is shown later. The model is first discussed in terms of its scope, level of detail and input desired. Then the structure will be presented.

What should be the *scope* of the model? Should it include field response activities, Be limited to the Communications Center, or be limited to a specific Communications Center activity?

The analysis of the Response Force has been divided into two parts: the Communications Center response and the field response. However, the distinction is not clearcut. Car assignment by the dispatcher is a function of field response characteristics.

Within the Communications Center, a useful distinction can be made between the handling of telephone inputs and radio transmissions. The average time that a call spends in the telephone input and handling stage of the process until it reaches the dispatcher amounts to 85 percent of the total average call handling time. Queues form infrequently at the dispatcher's station. Consequently, it was decided to concentrate on the processing of telephone calls. The total time span considered ends with the call (IBM card) being put in the dispatcher's queue.

The *level of detail* for the simulation model turned out to be a crucial factor. The main feature that complicates the analysis of the Chicago Police Department Communications Center is the interaction of a great number of events of very short duration, often no longer than 30 seconds.

One of the main questions to be answered by the model is the sensitivity of the system to the computer inquiry activity. This process does not consume a great deal of time, but it effectively reduces the telephone input handling capacity. Consequently, it was decided to model every transaction in the system.

The next point considered: generation of inputs or *exogenous events*. In a simulation model, these can be generated by the program or by actual events. When it is difficult or impossible to obtain data on specific events, or when events can be characterized by a theoretical distribution, it is often advantageous to generate the events. However, if the events are available and cannot be approximated by a theoretical distribution, the real events should be used. The latter applied here. The output from a simulation model depends on how realistically the real world has been modeled. Using generated events, when unnecessary, introduces one more element of uncertainty as to the validity of output.

Input to the Communications Center has to be characterized as to type (telephone call or PAX, the city internal system), priority (emergency, non-emergency and other), space and time. The events themselves were available and were used.

Data was collected for the third watch on Friday, December 13, 1968. Data on exogenous events collected for the model included radio dispatch calls, administrative calls, information inquiries, and no-service calls.

Figure 4-4 gives attributes of each call, keyed to the following numbers for type of call:

1. Radio dispatch (Bell or PAX).
2. Radio dispatch (radio or on-view).
3. No service (information).
4. No service (referral).
5. Traffic accident.
6. Vice Control dispatch.
7. Administrative call (radio).
8. Administrative call (PAX).
9. License.

Radio dispatch calls represent calls for which a car was dispatched. Administrative calls represent calls changing the status of a beatcar, such as lunch, personals, station assignment, etc. These come via PAX phone or by radio. The latter is included because the operator, when not busy, will often help the dispatcher handle administrative radio messages.

Information inquiry events consist of demands for information regarding cars and people, such as: Was the car stolen? Was a person wanted on a warrant? This information may come from the on-line computer inquiry system or via the "Hot Desk." The Hot Desk is a separate facility maintaining communication with State of Illinois files in Springfield and FBI files in Washington.

No-service calls are either calls which do not result in a beat car being dispatched (the IBM card is rounted to the Traffic or Vice Control desks) or are simply information requests from citizens or wrong numbers.

Data was also collected to determine the distributions for performing different unit operations, such as:

Time to complete information inquiry for stolen cars.

Time to complete information inquiry for warrants.

Both of the above operations.

Time to give information request to Hot Desk.

FIGURE 4-4: Attributes of Exogenous Event Types

Telephone Calls

1. Type
2. Scheduled time (in seconds from three o'clock);
3. Service time;
4. Beat car;
5. Zone;
6. Beat of Occurrence;
7. Verified Incidence Code.

Administrative Calls

1. Type (7 or 8);
2. Time out;
3. Time in;
4. Beat car;
5. Zone.

Information Inquiry

1. Type (9);
2. Time out;
3. Time in;
4. Zone;
5. Type (1, 2, 3, 4, 5).

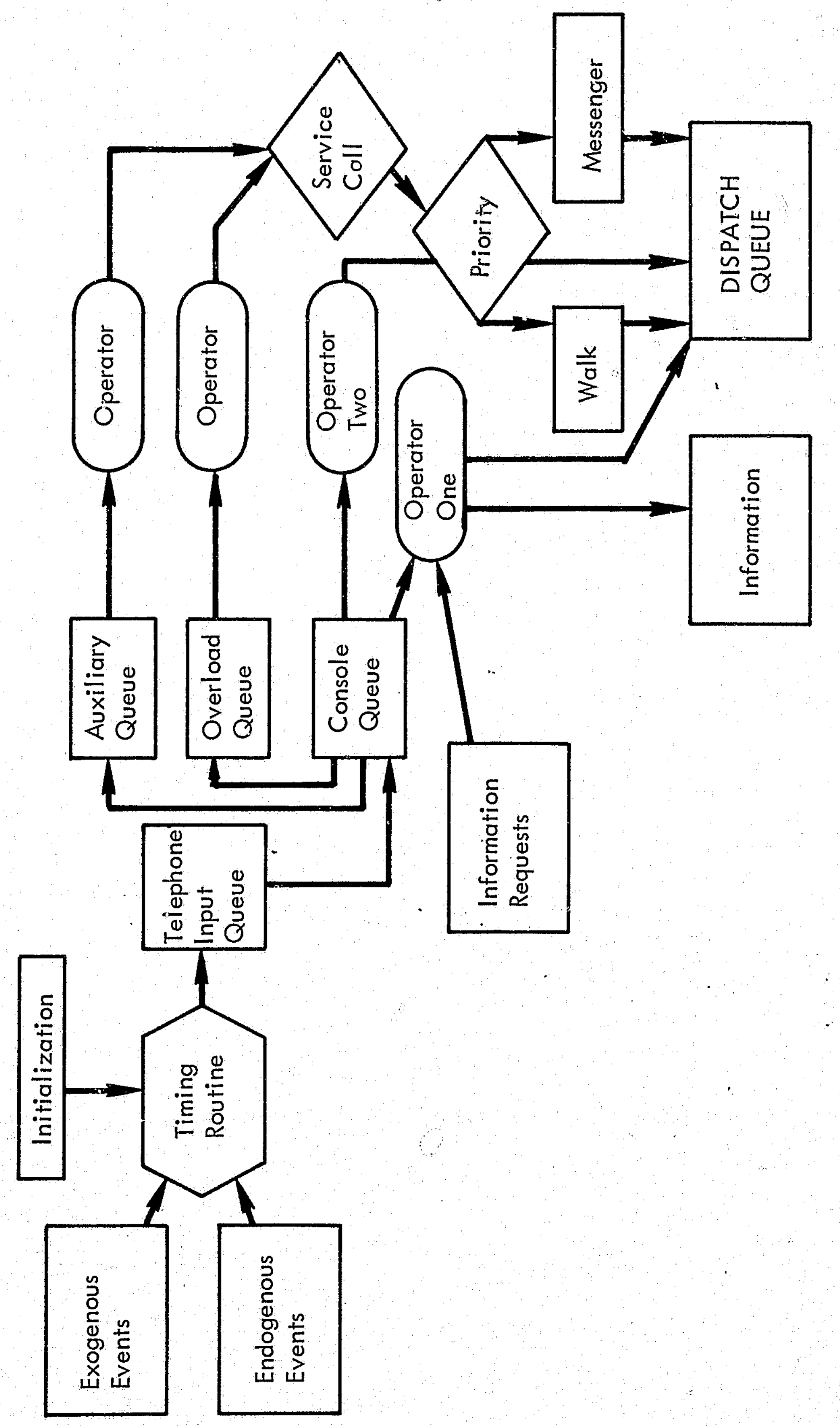


Figure 4-5 : Flowchart of Simulation Model of Communications Center

Time to handle return of information from Hot Desk.

Service time for a normal call.

Service time for a non-dispatch call.

Waiting time until messenger arrives to carry card from overload desks to console.

Time for card to be walked back from overload to console.

Time to walk from auxiliary desk to console.

Another difficulty in constructing a simulation model involves the choice of *clock routine.* The analyst may either use a fixed step increment or a next-event type of increment. The second alternative is often faster than the former and permits an accurate specification of when an event should occur. With the fixed increment alternative, the increment determines the resolution of the system.

In this simulation, a fixed increment of one second was chosen. Because of the necessity of checking the status of each queue for the 12 and 30-second intervals, and the short duration of each event, a fixed increment seemed justified. As the input data was accurate only to the nearest second, additional accuracy would have been illusory.

The *language* used for the simulation is Fortran with SPURT[4] subroutines. GPSS was not available at the Northwestern University Computing Center, and the Simscript compiler was not entirely reliable.

A simulation done in Fortran has several advantages. The language is easy, and its semantics are well defined, although it does not have a rigorous grammar. It compiles very fast in comparison to Simscript, and several subroutine packages are available for the simulation. SPURT is a set of subroutines based on Fortran and provides the generators for statistical summary macro-routines, special output packages, and a clock routine.

Conveying the complexity of the simulation model is difficult. The program is 2000 cards long, uses a core of 120,000 octal words, and takes 11 minutes to simulate eight hours of real time. A flowchart of the model is shown in Figure 4-5.

STRUCTURE OF THE MODEL

The program is initialized by a separate subroutine. This subroutine initializes relevant lists, reads in parameters, and brings up the initial events to be used in the timing routine. The timing routine causes the events (exogenous and endogenous) to appear as inputs. Endogenous events include the following event types, necessary for time-sequencing events and scheduled separately for each console:

Operator-one return.
Operator-two return.
Overload operator return.
Auxiliary operator return.
Administrative-PAX queue to be answered by operator.
Information returning from Hot Desk to operator-one.
Completed information card put in radio-out queue.
Radio dispatch card assigned to dispatch queue.
Administrative card put in administrative que for dispatcher.

Each call has 12 attributes as it is processed through the queues, including:

1. Type.
2. Time-scheduled (final time for statistic).
3. Time-on-service.
4. Beatcar.
5. Zone.
6. Beat-of-occurrence.
7. Verified incidence code.
8. Time call entered system.
9. Priority for assignment.
10. Time entering console.
11. Presence of call console, overload or auxiliary queues, for purging purposes.
12. Sequential number of call, for purging.

The *timing routine* is simply a Fortran array.

Incoming telephone calls are assigned to the telephone input queue. This permits loading of the system (more-demand, more trunk lines). If a trunk line is available, the call rings at the appropriate console. After 12 seconds, if unanswered, the call rings at the overload position; after 30 seconds, at the auxiliary position.

One of the console operators (called operator-one) handles information requests which are of five different types. An important question to be answered is the sensitivity of the system to performing this function in a separate facility. Calls are answered, and, if handled at the zone level, are put directly into the dispatch queue. If the overload facility has answered, the priority of the call determines if the operator or a messenger carries the IBM card to the dispatch queue. If the overload facility has answered, the priority of the call determines if the operator or a

The model includes several behavioristic parameters. These include:

1. Number of seconds after handling a call until the operator is ready to handle the next call.

2. Answering characteristic, i.e.—operator does not answer the call immediately, but may wait a couple of seconds; this is modeled with a uniform distribution.

3. Operator availability; operators leave their positions for short intervals to coordinate response with another zone or for personal reasons.

4. Proportion of administrative radio messages handled by operators. The operators often help the dispatcher by taking information and filling out the appropriate card.

5. Time distribution for answering calls. These differ between consoles, reflecting the type of calls and clientele demanding service. An operator may work different consoles on different nights; thus the difference in call handling time is a zone characteristic.

VALIDATING THE MODEL

The most difficult phase of constructing a simulation model is the validation stage. A theory of validation does not exist, and guidelines are almost nonexistent. The validation process can be subdivided into the following parts:

Validation criteria.
Exogenous event generation.
Probability distributions.
Model structure.
Initialization.
Parameters.

Criteria for validating the model include the average time to process a call, and the percentage of calls answered at console, overload and auxiliary desks. The Communications Center maintains daily records of where calls are answered. These records indicate the following:

Percentage of—	Dec. 13	Dec. (total)	Total 1968
Console........	53	53.25	53.3
Overload.......	31	35.85	35.6
Auxiliary.......	16	11.90	11.1

It is noteworthy that the percentages do not vary. The total volume of communications processed differs greatly between summer and winter. A linear regression was used to determine the relationship between number of incoming calls and percentage of calls answered at the console level. As can be seen in

Table 4–10

Linear Regression of Incoming Calls (3d Watch) Versus Percentage of Calls Answered at the Console Level

[Sample size per zone: 63]

Tone	$\bar{X}$	$\bar{Y}$	Y-intercept	Regression coefficient	T-value	Core coefficient
1	477	.40	.67	−.00056	−4.36	−.49
2	452	.47	.72	−.00056	−4.16	−.47
3	401	.73	.87	−.00035	−2.42	−.30
4	385	.58	.71	−.00033	−2.28	−.28
5	378	.67	.87	−.00054	−2.65	−.32
6	454	.60	.80	−.00044	−2.97	−.36
7	463	.60	.89	−.00062	−3.19	−.38
8	403	.58	.69	−.00027	−1.87	−.23

$\bar{X}$ = Average number of calls during third watch.
$\bar{Y}$ = Average percentage of calls answered at console.

Table 4-10, the regression coefficients are all significant at the 5 percent level of significance.

However the correlation coefficient is not very high. It is apparent that the load factor is not the only significant variable for explaining the percentage of calls answered at the console level. Other factors would include computer inquiry handling and the behavioral factors mentioned above. The difference between consoles, as shown in the table, can be explained by the differing nature of the calls and resulting service times.

The average time for service calls to be processed can be calculated. The mean duration of the different unit operations and the percentage of calls answered at the console, overload and the auxiliary desks are known. The average time was 81.9 seconds. (Table 4-11)

Table 4–11

Determination of Average Time for Calls To Reach the Dispatch Queue

Desk	t1	t2	t3	t4	t5	Proportion (percent)	t6	t7
Console....	36.2	25	2	0	0	53	63.2	33.5
Overload...	36.2	25	2	13	21	31	97.2	30.13
Auxiliary...	36.2	25	2	30	21	16	114.2	18.27
System average..........								81.90

t1 = Time to take a call, seconds.
t2 = Time to fill out the IBM card, seconds.
t3 = Time interval in which the operator decides to answer the call, seconds.
t4 = Step-up interval.
t5 = Time to transport IBM-card to console.
t6 = Average time at this level.
t7 = Weighted average.

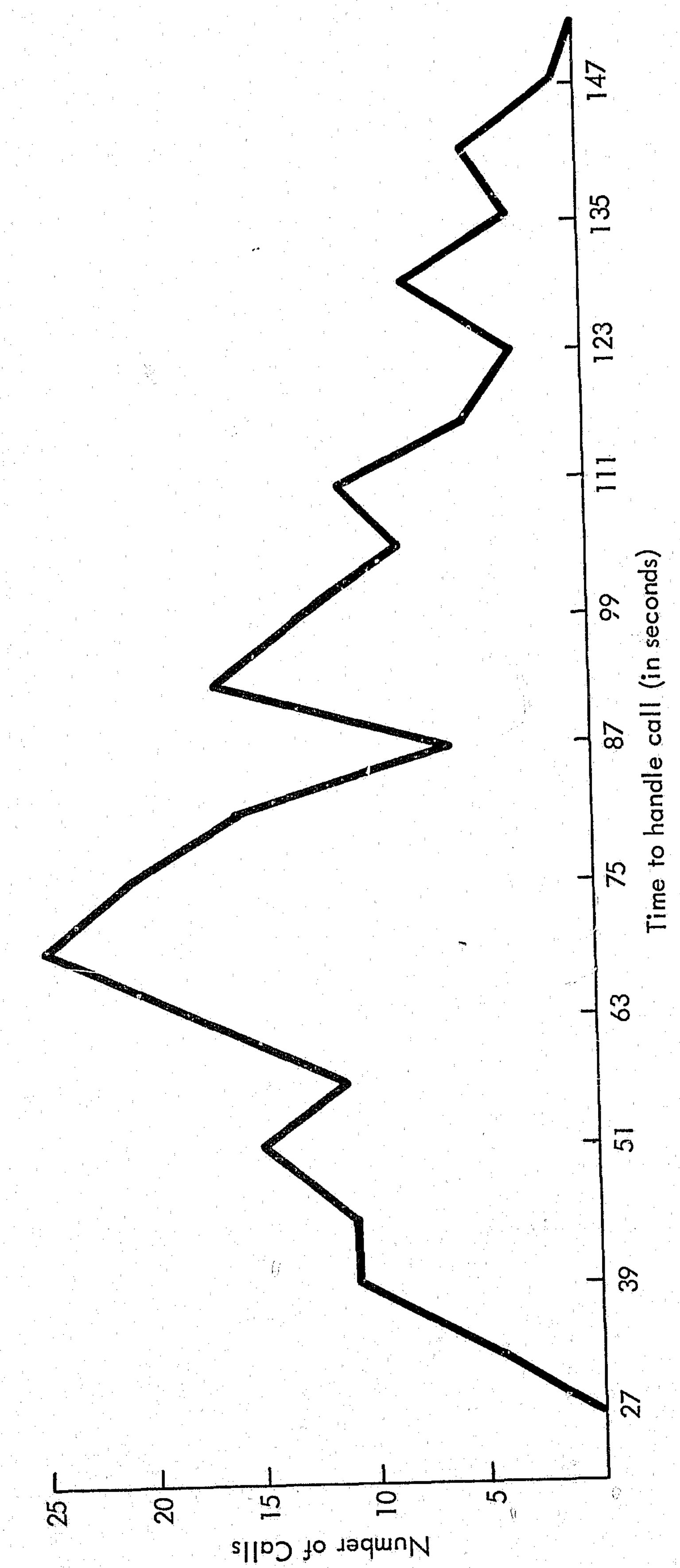


Figure 4-6 : Service Time Distribution for Communications Center (until call reaches dispatch queue)

The exogenous events consist of all the actual events for a given time period. Therefore this part of the simulation model did not pose any difficulties. The probability distributions for completing the unit operations were determined by taking samples of their duration. These distributions were then used to specify cumulative probability distributions which were validated against the original data by Chi-square tests.

An important consideration for simulation models is the start-up interval. How long should the model run before the influence of the starting conditions is not significant? By investigating the status of the different queues in the model, an hour of simulated time was determined to be adequate.

The model would not provide reasonable values until the behavioristic parameters, mentioned earlier, were introduced. It was assumed that the operator would need a five-second "breather" between calls, and that the administrative calls would be handled by the operator when he was not busy. Sensitivity of the model to the behavioristic parameters was determined, as shown in Table 4-12.

The answering characteristic and downtime for the different operators gave the best fit to real world statistics for:

1. Answering characteristic equal to two seconds.
2. Console operators away from their positions for two minutes each, per hour.
3. Overload operators not available for seven minutes each, per hour. (This is realistic as the overload operators have other duties to perform.)

Table 4–12

Sensitivity analysis of behavioristic parameters

A	B	C	D	E	F	G	H
2	2	240	400	94.5	53	41	6
2	4	400	600	88.0	55	40	5
2	2	60	420	93.3	57	40	5
2	2	120	420	83.1	54	41	5
2	4	300	300	88.9	57	39	4
2	2	120	500	88.1	55	39	6
2	2	300	600	91.3	55	40	4
2	2	120	300	88.6	53	43	5
2	2	120	600	91.2	53	42	6
2	2	120	300	85.8	52	44	5
Actual performance Dec. 13, 1968				81.9	53	31	16

A = Answering characteristic in seconds at console.
B = Answering characteristic in seconds at overload.
C = Seconds that operators are not available at console.
D = Seconds that operators are not available at overload.
E = Average throughput time.
F = Percentage of calls answered at console.
G = Percentage of calls answered at overload.
H = Percentage of calls answered at auxiliary.

The random number generator was initialized with different values to indicate the variance due to pseudorandom numbers. This variance had approximately a two-second effect on the average.

RESULTS OF THE MODEL

The questions to be investigated were priority classes, number of trunk lines, step-up intervals, computer inquiry at consoles and assignment of manpower.

The validated model which becomes the reference point had an average of 83.1 seconds and a standard deviation of 32.9 seconds.

A two-priority system will have a shorter response time for priority-one calls. The time saving is realized where the overload or auxiliary operator walks the IBM card over to the appropriate console instead of waiting for the messenger to arrive. Since half of the calls are not answered at consoles, and the waiting time is eight seconds, the saving is four seconds plus the shorter wait in the dispatch queue. (Fig. 4-6)

The current number of trunk lines is not a limiting factor. Statistics are collected on the number of occurrences when all seven lines are busy and an eighth-call tries to enter. It is infrequent in the real world during winter season.

The step-up intervals are currently set at 12 and 30 seconds. By lowering the step-up interval, more calls will be answered at the overload. The time before a call is answered will be less, but the 21-second average for being transported back to the console would have to be added. (Assuming our reference point to be the true population estimate, a t-test can be used to determine how large a difference of means is necessary for the sample mean to be significant. At the 5 percent level of significance, a difference between means of four seconds is necessary). The results:

Varying Step-up Intervals

Step-up interval (seconds) 1	2	Average (seconds)	Standard deviation
5	30	84.7	36.3
10	30	86.5	35.1
13	30	83.1	32.4

Step-up interval No. 1 = from console to overload desks.
Step-up interval No. 2 = from console to auxiliary desks.

As can be seen, the current intervals are well chosen for the kind of load experienced on December 13.

How important is the computer inquiry activity at the console? The activity was deleted from the model, and there was no significant change.

Deletion of Computer Inquiry

Step-up interval (seconds) 1	2	Average (seconds)	Standard deviation
13	30	83.69	38.57
5	30	82.85	30.20

The deletion of the Computer Inquiry activity did not have a significant influence on the average throughput time.

Lastly, manpower levels were considered. The second position at the console was augmented by one man, and the overload desk brought to its full strength of nine.

Manpower Augmentation

Step-up interval 1	2	Men at position 2	Men at overload	Average (seconds)	Standard deviation	Comment
13	30	2	6	77.76	31.7	No
5	30	2	6	74.70	33.2	Sander's
5	30	2	9	73.40	30.34	Inquiry

FIELD RESPONSE SIMULATION

Field response is defined as the activities performed by a police unit after it has been assigned and until it has completed the assignment.

The total response time consists of Communications Center response time and field response. It was pointed out in the previous chapter that the waiting time of a call in the dispatch queue, until a car becomes available, depends on assignment policies and the availability of cars. It becomes convenient to consider the impact of stacking and screening policies in the context of the field response model.

The measures of effectiveness of the Response Force were defined to be:

1. The level of service for the Public Service type calls. (This would include the rapid response needed for sick and injured transport and the less urgent calls that could be stacked or screened.)

2. The crime disutility represented by the cases not dismissed by the court for incorrect police behavior. (This measure included the probability of apprehension and its qualitative aspects.)

It was noted earlier that the probability of apprehension is a function of the number of police units responding within a given number of minutes. This refers to the use of trapping and search procedures to capture an offender. Police units would be assigned from those available, including the Preventive and Follow-up forces. However, it is very likely that the availability of the Response Force proper in an area will be an important variable.

The analysis of the field response activities entails a complex analysis of the effect of the following variables on Response Force efficiency:

1. Demand.
2. Service time.
3. Travel time.
4. Number of units in Response Force.
5. Total number of police units in the field.

This section includes analytical methods for determining the demand for services and the positioning of forces, an analytical model by Richard Larson and a simulation model of field activity. Several alternatives are evaluated, and the effect of response time on the probability of arrest is shown.

In order to optimally allocate patrol manpower in space and time, with respect to future demand, police must be able to forecast demands for service. Various techniques are available to do this.

The Philadelphia Police Department has tried to use multidimensional analysis and multiple regression techniques.[5] The former technique assumes that crime occurrences can be predicted from factors which co-occur with crimes. The objective would be to input values of crime factors and determine a probability of a certain crime type occurring at a given space/time. Table 4-13 gives these factors.

However, estimating the likelihood of a criminal event occurring in space/time requires knowing in how many instances a specific occurrence of factors did not result in a crime. This information is not available. Consequently, use of this technique for predictive purposes for Response Force allocation is not recommended.

Another difficulty is that although multi-dimensional analysis is a very powerful technique, it can only be as good as its input data. It is extremely difficult to get up-to-date socioeconomic information and accurate weather predictions. The weather is often an important explanatory factor.

Table 4–13

Philadelphia Crime Prediction Factors.[6]

Day of week.	Percent with 1.01 or more Persons per room.
Month.	Percent married.
Day.	Percent foreign born.
Hour.	Percent growth.
Phase of moon.	Percent decline.
Snow.	Percent moved.
Visibility.	Percent of families (1 or more under 6 years).
Precipitation.	Percent nonwhite.
Wind speed.	Percent enrolled in school.
Temperature.	Average income.
Relative humidity.	Average persons/house.
Pressure	Average rent.
Age percent 15–34.	Average school years completed.
Age percent 60 and over.	Number of transit interchanges.
Percent males unemployed.	Number of elementary schools.
Percent wage and salary workers changes.	Number of junior highs.
Percent owner-occupied housing.	Number of senior highs.
Percent sound housing.	

Even with the above limitations, the analysis should yield valuable inputs to a crime prevention program. The most likely locations and time of occurrence could be pinpointed so as to receive increased attention. The problem of preventive patrol is mainly one of space/time coincidence between a police unit and a misconduct.

Forecasting police calls for service must precede the actual implementation of efficient methods for manpower allocation. Calls for service fluctuate according to city location, hour of the day, day of the week, and week of the year. This fluctuation in calls for service causes a time-varying workload and, hence, a necessity to design an algorithm for a time-varying work force.

For purposes of patrol allocation, any call for service that prompts the dispatcher to send a patrol car must be considered. In this context, the weightings assigned to Part I and Part II crime or other calls to determine beat structure have no meaning. Police resources are equally taxed if a patrolman assists a woman locked out of her house or if he takes a report on an auto theft. Naturally, the types of calls will determine the relative numbers of one-man and two-man squad cars for each district by time of day, day of week and week of the year must be forecast to determine the necessary numbers of patrol cars.

St. Louis used one type of forecasting in setting up its split force, separating preventive patrol from service forces. The forecast for calls can be coupled with a queuing analysis to show the numbers of service units necessary to furnish predetermined service levels.

Service level refers to the expected waiting time before a call receives service. If large service forces are used, a car could always be available. A call priority system offers one way of reducing the service force while insuring quick response to urgent calls. Under a priority system, top priority calls receive immediate response, and lower priority calls must wait until a unit is free for service.

The St. Louis study used an exponential smoothing technique to forecast calls for service. This model included a multiplicative seasonal factor, but it did not include an additive or multiplicative trend factor. Since calls for service are generally higher in 1968 over corresponding weeks in 1967, a trend obviously exists. While the St. Louis approach has worked, the Chicago model included an additive trend. Thus a change of police tactics or a change of criminal behavior will appear as a trend. The isolation of trend will provide other management information relating to the effectiveness of crime prevention efforts.

A simpler forecast method is based on the similarity of a given week's activity with the same week for the previous year. If a trend adjustment is made to the weekly total calls for service for last year, the resulting linear predictor is highly accurate. This approach is discussed in detail later. This indicates that the generation process of calls for service, specifically miscellaneous non-criminal calls for service, is remarkably stable.

SMOOTHING DATA FOR INPUT

Many techniques are used to smooth observed data for computational purposes. The most familiar method is the arithmetic average. If a machine is set to fill sacks with 100 pounds of wheat, and five sacks weigh:

101.41 lbs.
101.05 lbs.
98.43 lbs.
99.75 lbs.
99.36 lbs.

Total: 500.00 lbs.

Then the average weight per sack is 100 pounds. If a truck were loaded with 50 sacks, the total load would be computed at $50 \times 100 = 5000$ pounds. In this case, the smoothed or average weight provides a better estimate of the truck load than multiplying any of the individual observed weights. Naturally this assumes that the other 45 sacks were filled in the same manner.

Another type of smoothing often used with time series samples is the moving average. In this case, the most recent N samples are averaged:

$$M_4=\frac{X_1+X_2+X_3+X_4}{N} \qquad (1)$$

where $N=4$, and $X_1, X_2, \ldots X_i$ are the first, second and i^{th} samples in the time series. M_4 is the first moving average. M_5 and M_6 are found by computing as follows:

$$M_5=\frac{X_2+X_3+X_4+X_5}{4} \qquad (2)$$

$$M_6=\frac{X_3+X_4+X_5=X_6}{4} \qquad (3)$$

The moving average will provide nearly the same estimates as the arithmetic average if the underlying process is constant, and if N is large. If the underlying process changes (suppose the machine loading wheat in the sacks was changed to put 110 pounds in each sack) the arithmetic average will give a poorer estimate than a moving average, which will average samples taken exclusively from the new process after N observations. As an example, consider the following weights:

(Machine set to put 100 lbs/sack)

X_1	X_2	X_3	X_4	X_5
101.41	101.05	98.43	99.75	99.36

(Machine set to put 110 lbs/sack)

X_6	X_7	X_8	X_9	X_{10}
111.29	108.37	110.09	109.20	111.05

The arithmetic average of the ten sacks is

$$\frac{500+550}{10}=105 \text{ lbs/sack}$$

A moving average of $N=4$ would give estimates

$M_4=100.16$ lbs/sack
$M_5=99.64$ lbs/sack
$M_6=102.21$ lbs/sack
$M_7=104.69$ lbs/sack
$M_8=107.28$ lbs/sack
$M_9=109.74$ lbs/sack
$M_{10}=109.68$ lbs/sack

Thus the 10 sample weights provided seven moving averages, using four samples per average. M_6, M_7, and M_8 were responding to the change, but only M_9, and M_{10} were computed from data taken exclusively from the new process. Since the data was arranged to provide average weights of 100 and 110 pounds on five samples, none of the moving averages gave these weights. If the number of terms in the moving average were decreased, the averages would have shown the loading process change more quickly. But the values would also show more fluctuation about the 100-pound and 110-pound values. The trade-off between response and stability determines the best value of N.

The moving average follows trends, and the technique can be used to remove seasonal effects. In this respect, the moving average system could be used with the Chicago Police calls for service data. As seen by the numerical examples, the moving average requires the storage of N-data samples and a recomputation with each new sample. For the police case, calls in a given week in a police year correspond better to the same week in the previous police year than the preceding week of the same year. Also, Fridays behave more like the Friday a week ago than the preceding Thursday. The same observation holds for hours in the day. This would indicate the need for averaging over several years such data with moving averages to remove the periodic effects of seasonal, daily and hourly variations. Moving averages would require the computer storage of a great many data points.

To avoid the storage problem, exponential smoothing is often used. Considering just a trend component, the moving average is computed from successive samples

$$X_1X_2X_3X_4X_5X_6X_7X_8X_9X_{10}$$

$$M_6=\frac{X_2+X_4+X_5+X_6}{4} \qquad (4)$$

where $N = 4$

The next moving average could be computed as

$$M_7=M_6-\tfrac{1}{4}X_3+\tfrac{1}{4}X_7$$
$$=\tfrac{1}{4}(X_7-X_3)+M_6 \qquad (5)$$

where X_7 is the newest sample and X_3 is the oldest sample in the time series. In general, the t^{th} moving average is written

$$M_t=\frac{1}{N}(X_t-X_{t-n})+M_{t-1} \qquad (6)$$

In equation (6) the new moving average is computed from the previous moving average, the newest time series sample, and the oldest time series sample used in the previous moving average. If the oldest time series sample were not retained, the best estimate of X_{t-n} is M_{t-1}. Thus, a similar type of moving average could be computed as

$$M_t{}^*=\frac{1}{N}(X_t-M_{t-1})+M_{t-1} \qquad (7)$$

If this method is used to compute all successive moving averages, the equation is rewritten as

$$S_t=\alpha x_t+(1-\alpha)S_{t-1} \qquad (8)$$

where α is a coefficient like $\frac{1}{N}$, but not equivalent.

Equation (8) is the general exponential smoothing form, and the only information retained for computation is the previous smoothed value S_{t-1}, the coefficient α, and the newest data sample X_t from the time series. The coefficient α is a number $(0\leq\alpha\leq1)$ which increases the response to a change if large, and increases the stability if small. The effect on the new estimates, S_t, is to weight the older samples in an exponentially decreasing manner. Hence, the reason for calling this technique exponential smoothing.

Equation (8) works on a process which does not change, or changes very slowly. Police calls for service have seasonal, daily and hourly variations of an almost periodic nature. In this case, a seasonal effect should be incorporated to adjust the data. If a linear trend exists, this term should also appear. St. Louis uses ratio seasonal and hourly (hour of the week) factors—but no linear trend component. Considering only the seasonal ratio, this form is

$$S_t=\alpha\frac{X_t}{W_{t-L}}+(1-\alpha)S_{t-1} \qquad (9)$$

where $$W_t=\beta\frac{X_t}{S_t}+(1-\beta)W_{t-L} \qquad (10)$$

In these equations, S_t is a weighted sum of the current estimate obtained by de-seasonalizing the current calls for service in the t^{th} period, x_t, and the previous period's estimate, S_t-1, of the smoothed and seasonally adjusted calls for service. References 7-11 discuss this method further. The seasonal effect, W_t, is again a weighted sum of the current estimate, $\frac{X_t}{S_t}$, and the previous estimate W_{t-L}, where L is the periodicity. If the periods of forecasts are hours of the week, the periodicity is 168. Thus W_t is adjusted by using several years of data to obtain a smoothed seasonal factor for each of the 52 weeks of the police year. A forecast for period T, based on observation through period t is given by

$$\hat{S}_t, T=S_tW_{t-L+T} \qquad (11)$$

St. Louis used a periodicity of 53 weeks. The Chicago Police used a 13-period system for crime reporting. Each period consisted of four weeks. The police year always begins and ends on the same day, Thursday and Wednesday respectively; comparisons between periods from different years and successive periods of the same year have greater validity than normal monthly statistical periods since each period contains the same number of weekends. For this reason, the Chicago system will use a periodicity of 52 weeks.

The police year of 364 days requires correction since the date of the first day moves progressively backwards. Christmas and New Years are kept in the Thirteenth period to permit valid yearly comparisons of this period. If the first police year began on 4 January 1964, it would end on 31 December 1965, which splits Christmas and New Years. This problem is avoided by starting the police year on 9 January 1964. A correction of one week is then necessary after five years. In other words, a police year will end on 1 January 1969 and begin on 9 January 1969. While the usual comparison would not be made for the "skipped week" since no exact equal exists; predictions of calls for service for the first week of the police year will be used for this week also. This instance arises only in 1969, 1975 and 1980 between now and 1983.[12] Christmas and New Years will split into different weeks by this system. This difficulty is not considered serious and can be treated exponentially for manpower allocations.

In order to predict for hour-in-the-week, St. Louis used an exponentially smoothed series based on normalized values of the average calls for service by hour-of-the-week. The hourly factor is given by:

$$H_k=\gamma\frac{Y_k}{\bar{Y}}+(1-\gamma)H_{k-m} \qquad (12)$$

where k is the hour of the week $(1\leq k\leq168)$, Y_k is the actual number of calls for the k^{th} hour, $\bar{Y}$ is the average number of calls per hour, m is the periodicity, 168, and $(0\leq\gamma\leq1)$ is the smoothing coefficient. The prediction for the r^{th} hour of the T^{th} week, based on data through week t is given by

$$P_r=\frac{\hat{S}_{t,T}}{168}H_r \qquad (13)$$

This does not change the total prediction for the week since

$$\sum_{r=1}^{168} P_r=\frac{\hat{S}_{t,T}}{168}\sum_{r=1}^{168} H_r=\hat{S}_{t,T} \qquad (14)$$

Here the index r is used instead of k since k refers to an hour of observed data in the t^{th} week. The hourly adjustment was based on the last observed data.

The quantity $\left(\frac{\hat{S}_{t,T}}{168}\right)$ is the forecast average number of calls per hour for the T^{th} week in the future. The hourly factor H_r distributes these calls in the same manner throughout week T as the smoothed observations H_k which were based on hourly observations in week t.

Initially, St. Louis removed the seasonal component of the data by hour of the week. Their model then became

$$S_t=\alpha\frac{x_t}{W_{t-L}H_{k-m}}+(1-\alpha)S_{t-1} \qquad (15)$$

Since St. Louis predicts 10 categories of calls for rather small geographic areas, the H_{k-m} term became very close to zero in some cases. Division of the first term in equation (15) by a number close to zero caused instability with the smoothed series. For this reason, equation (13) was used instead of equation (15) to forecast calls by hour.

Equations (9 and 13) do not consider a linear trend. However St. Louis has used this equation to successfully forecast calls for service by hour. Other forecasters[7] point out, however, that if a trend exists and the model does not account for it, then the seasonal factors will soon contain a trend effect. If the series of calls for service contain short-run trends of duration less than L (52 weeks), then the trend effect incorporated in the seasonal factors is made up of short-run trend effects from previous years' data. This can introduce erratic behavior in the seasonal adjustment and the smoothing of S_t that probably will upset the forecast.

An additive or linear trend would alter equation (9) to

$$S_t=\alpha\frac{X_t}{W_{t-L}}+(1-\alpha)(S_{t-1}+R_{t-1}) \qquad (16)$$

where the expression for revising the trend estimate is

$$R_t=\eta(S_{t-1})+(1-\eta)R_{t-1} \quad (0\leq\eta\leq1) \qquad (17)$$

which again weights the estimate based on current data with the previous estimate. The forecast equation for the T^{th} week is written as

$$\hat{S}_{t,T}=[S_t+TR_t]W_{t-L+T} \qquad (18)$$

Computationally, equation (18) would be implemented by the following steps:

(1) Record the actual calls for service during the t^{th} week—x_t.

(2) Use equation (16) with S_{t-1} and R_{t-1} from the last period and W_{t-L} from the previous cycle to evaluate S_t.

(3) Using the hourly record of actual calls for service during the t^{th} week—Y_k, evaluate H_k from equation (12), which will now replace H_{K-M}.

(4) Use equation (10) to compute a new W_t, which will now replace W_{t-L}.

(5) Use equation (17) to compute a new R_t, which will now replace R_{t-1}.

(6) Use equation (18) to forecast the number of calls for service in week T.

(7) Use equation (13) to forecast the number of calls for service by hour in week T.

(8) Compute the error from previous forecasts by the formula

$$e_{t,T}=X_{t+T}-\hat{S}_{t,T} \qquad (19)$$

(9) Using the error computation from equation (20) compute the standard deviation of error

$$\sigma_e=\left\{\frac{\sum_t e_{t,1}}{N-1}\right\}^{1/2} \qquad (20)$$

where t is summed over the set of N observations used for estimation.

Initializing the Estimates

The Chicago Police Department has records by district for daily radio dispatch cards dating back for several years. This data can be used to get smoothed estimates of the seasonal factor and the linear trend. The only data not recorded (although available from computer tapes of the radio dispatch cards) is the hourly distribution by police week. However, a few weeks of observation will yield the same number of terms for computing smoothed estimates as several years of data will provide for the weekly smoothed estimates. The error analysis for hours of the week will require this data, but the total weekly forecasts can be tested on portions of the older data.

Using a portion of the older data, the first H weeks (more than one year) are taken to perform the following steps:

(1) Compute the average calls for service each week for the i^{th} year, V_i

(2) Compute the average trend R_{last} (or R_{t-1} when in the t^{th} period) as

$$R_{last}=\frac{[V_{H/L}-V_1]}{[H-L]} \qquad (21)$$

(3) Use $S_{last}-V_1$, the average calls for service per week for the first year, as the initial estimate of S_t.

(4) Compute seasonal factors for each period $t=1,\ldots,H$ according to

$$W_t=\frac{x_t}{V_i-\left(\frac{L+1}{2}-j\right)R_{last}}, \qquad (22)$$

where the subscript i refers to the year contained in the H periods and j refers to the number of the week in the ith year, hence $t=(i-1)L+j$

(5) Compute 52 values of W_t for each week in the police year and retain, using the average value of corresponding weeks if more than one year is used to initialize.

(6) Normalize the seasonal factors so

$$\sum_{j=1}^{52} W_j=52$$

by

$$W_j=\text{Average } W_j\left(\frac{L}{\sum_{j=1}^{L}\text{Ave } W_j}\right) \qquad (23)$$

Step (6) guarantees that the seasonal factors only make seasonal adjustments, and so the factors will not increase or decrease the average calls for service—namely, the trend factor.

Selection of the Weights

The best set of values for the four weights $(\alpha,\beta,\gamma,\eta)$ can be selected by a trial and error system. Following the cited practices,[7,8] a matrix of 11 values for each weight would be used to test the forecast against a portion of the known data. Equation (20) provides a measure of the standard deviation of the forecast error. The computer could sequence through all possible combinations of weighting values ($11^4=14{,}641$ possible combinations using values of 0.0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, and 1.0 for each of the four weights), and choose the combination which minimizes equation (20).

Winters and Holt, et al state that the function σ_e is convex in the area of the minimum. If the curve is somewhat flat, a finer grid to locate values of weighting functions beyond a single decimal (i.e. 0.13, 0.17 instead of 0.1 and 0.2) probably is not worth the effort. A flat minimum is indicated in the references.

Other criteria of error could be used instead of the standard deviation of forecast error. In fact, the applicability of this criterion assumes that the forecast errors are unbiased so that an estimate of the standard deviation of forecast errors is indeed given by equation (21). If forecasts for several weeks were made, the accuracy for the later weeks might decrease in importance. Winters[7] suggests the minimizing of a criterion function.

$$U=\sum_t(a_1e_{t,1}^2+a_2e_{t,2}^2+a_3e_{t,3}^2) \qquad (24)$$

where $a_1>a_2>a_3$ and possibly $(a_1+a_2+a_3)=1.0$.

Since the application concerns a queuing model in the Chicago Police Department, the criterion could be the minimization of the absolute value of the error, $/e_{t,T}/$ or a minimization of the error caused by underestimating the actual calls for service, $e_{t,T}>0$. The latter criterion would minimize the instances of assigning insufficient manpower to handle calls for service at the price of a somewhat wasteful allocation, on the average. Once the error criterion has been chosen, the best values for the four weights can be found by successive trials.

Police departments with adequate data can immediately use this type of forecasting by modifying the output of two existing programs, one available from IBM[13] and the other from Control Data Corporation[14]. Each program uses historical data to initialize the seasonal factors and the trend factors in addition to finding the *optimum* weights.

In the IBM Share Program the weights α, β, η (in this paper) are selected on the basis of minimizing equation (20). The other program by CDC calculates equation (20), but selects those weights which minimize the average fractional error (AFE) given in equation (25)

$$AFE=\frac{\sum_t -e_{t,T}}{\sum_t X_{t+T}} \qquad (25)$$

These programs can supply the forecast by the week. The hourly forecast can be obtained from this output by using equations (12) and (13) on portions of the historical data. The choice of the weight γ can be selected as the one that minimizes the hourly forecast error. Because of the form of equation (13), the selection of γ can be made independent of α, β, η. While this method would not be used if a program were specifically designed for selecting the weights of an hourly forecast routine, the ease of implementation with the existing programs recommends the approach. The IBM program is a contribution to the IBM Share Library. The program was written in 1963 for running on the IBM 7090/94.

The CDC program is written for the 3600 and is available to CDC customers. These programs are used only once for the selection of weights and the initial calculation of the seasonal and trend factors. The user would then write a simple routine employing equations (16), (17), (10), (12), (18) and (13) to continue the forecasts and the updating of the seasonal and trend factors.

Using Hand Graphical Method

The Hand Graphical Method permits estimation of the necessary number of response units without using a computer. The strong seasonal character of calls for service that was noted in *The Second Quarterly Progress Report* of the Operational Research Task Force for

Table 4–14

Response Units Required To Answer Calls for Service, Summer 1969

Time	District 14						
	Mon.	Tue.	Wed.	Thur.	Fri.	Sat.	Sun.
01	7	7	6	7	7	11	11
02	6	6	6	5	5	10	11
03	5	4	5	5	5	9	8
04	4	4	3	4	4	6	7
05	4	4	3	3	4	6	5
06	3	3	3	3	3	4	4
07	4	4	4	4	4	4	4
08	6	6	6	6	6	5	4
09	6	6	6	6	6	6	6
10	8	8	7	7	8	7	5
11	8	7	7	7	8	7	6
12	8	8	8	8	8	9	8
13	8	7	8	8	8	10	8
14	8	8	8	8	8	10	8
15	9	8	8	9	9	10	9
16	10	10	10	10	10	10	10
17	11	10	11	10	11	11	9
18	13	12	13	12	14	12	10
19	14	13	15	14	14	15	15
20	16	15	16	15	15	14	14
21	15	15	15	15	16	15	16
22	15	12	14	12	17	15	14
22	10	14	11	11	17	18	15
24	8	9	8	9	11	13	10

Chicago as a whole exists also in each Police District. Thus it has been possible to employ a linear predictor to estimate calls for service. Further, it has been found that the calls for service on each day occur in a nearly unvarying pattern. Thus it is possible to estimate expected calls for service per hour for each hour of the day and each day of the week.

Methodology for Estimating the Required Units for a Response Force

Figures 4-7, 4-8 and 4-9 graph the results obtained by computer for inputs of the rate of arrival of calls for service per hour, for average service time, and the number of units. The graphs provide for a service level based on the criteria that an incoming call will have to wait less than five minutes before a unit is free to provide service. Plots are also provided for lesser average waiting times.

Instructions for Use of Beat Car Assignment Graphs

(Figs. 4-7, 4-8, 4-9)

1. Enter at left with number representing calls for service expected.
2. Proceed to curve that represents district experience at time of day.
3. Draw line to intersection with bottom scale. This tells number of cars needed.

Ex. Calls for service = 5/hour
Service time = 20 min.
Cars needed = 6

For average wait of an available car less than six seconds.

The constraint of minimum travel time is met by creating square beats (within limitations imposed by topography) in which the expected travel time does not exceed three minutes.

Application of the Hand Graphical Method was made to the 14th Police District. The level of calls for service per hour was forecast for the Summer of 1969 using a multiplication factor of 1.24 times the daily level of 1968. Table 4-14 shows unit requirements by hour of the day and day of the week.

Positioning Patrols

The positioning problem (or manpower distribution problem) has two dimensions. One is the assignment

Figure 4-7 : Number of cars needed to limit average wait for available car to five minutes.

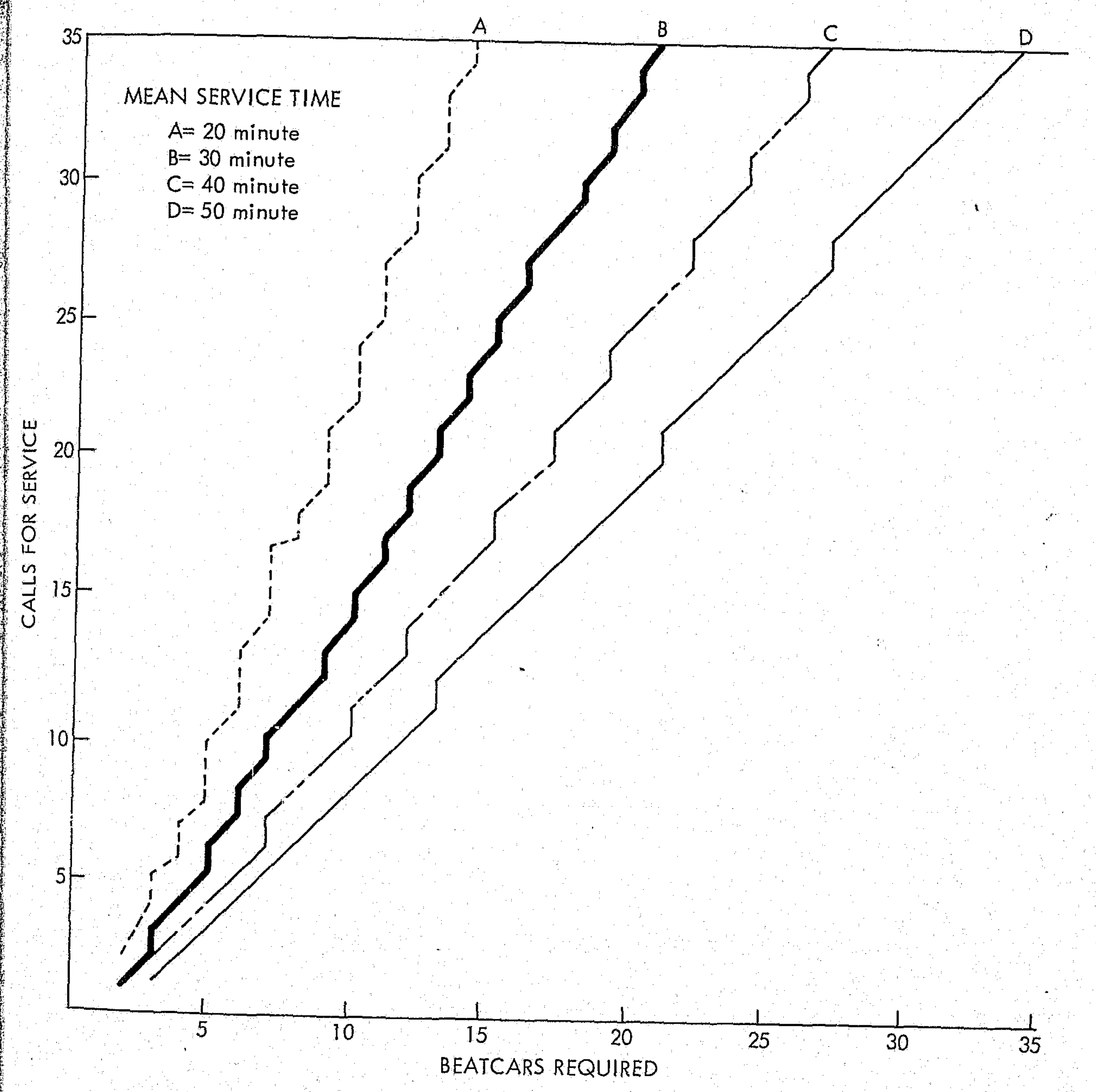


Figure 4-8 : Number of cars needed to limit average wait for available car to 2.5 minutes.

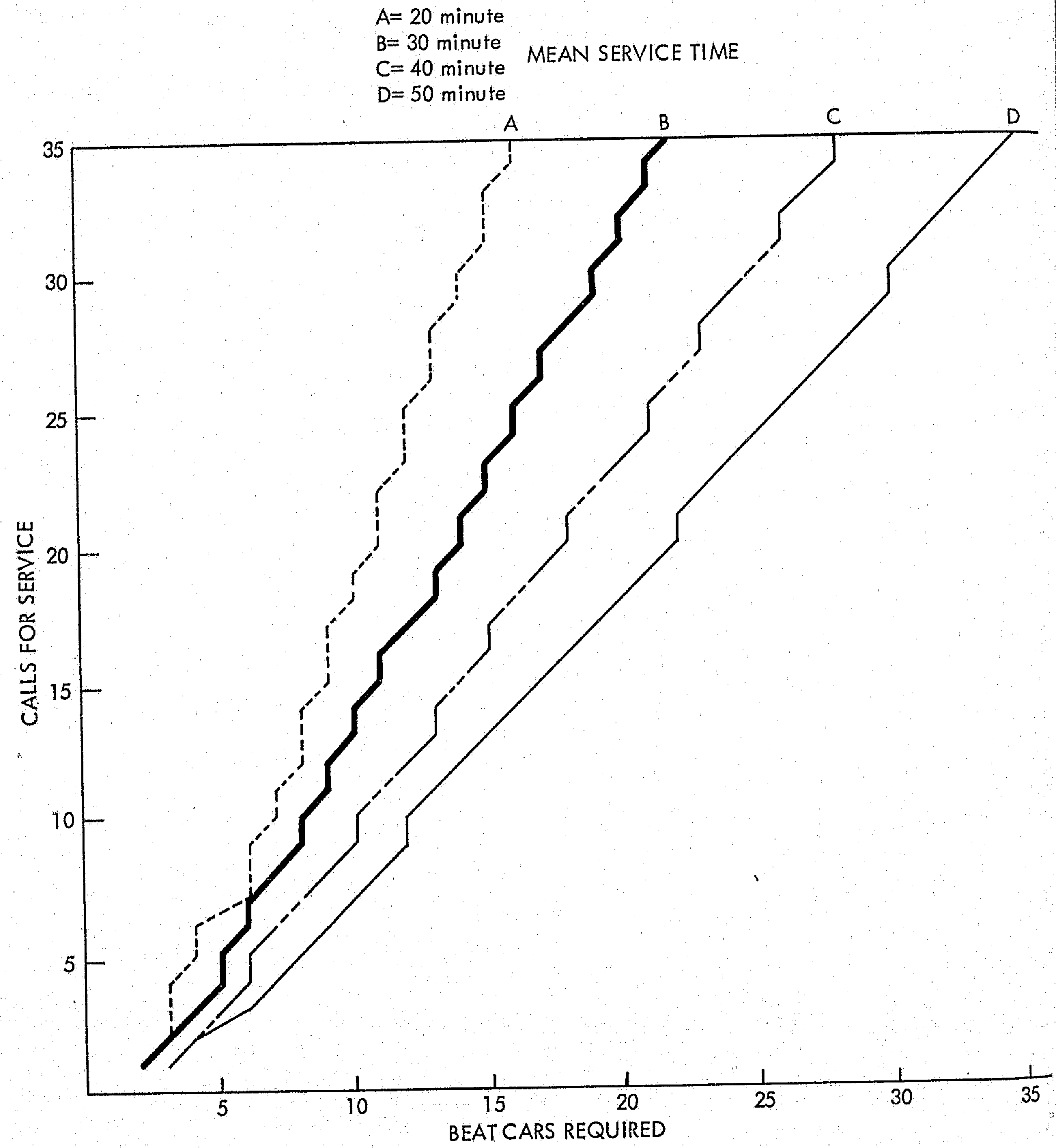
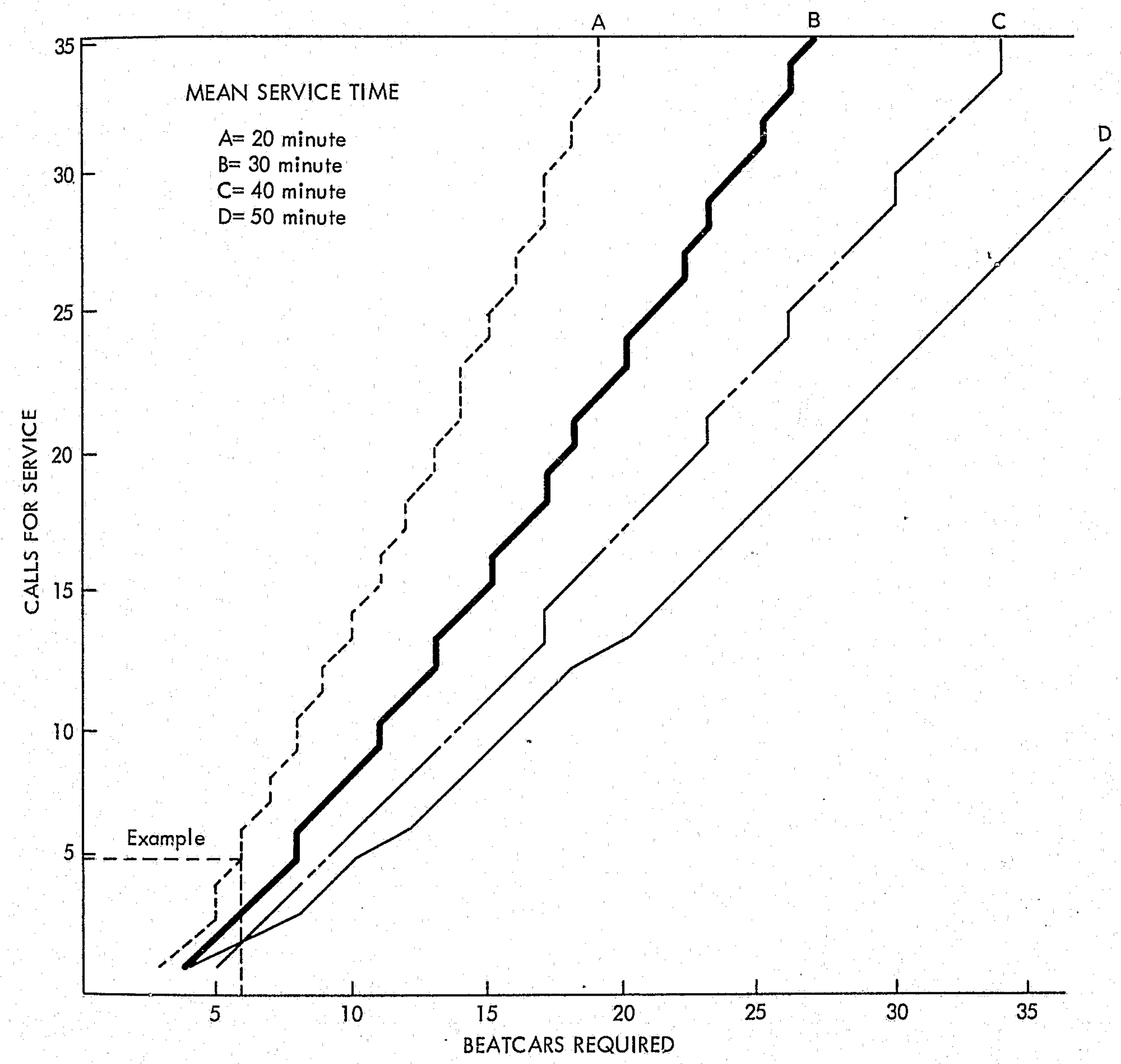


Figure 4-9 : Number of cars needed to limit average wait for available car to 0.10 minutes (6 seconds)



of police units to sectors—called districts in Chicago—and the initial positioning of units within the sector, the beat structure.

Several possible criteria exist for assignment.[15]

1. Equalize workload.
2. Equalize weighted workload.
3. Minimize response time.
4. Minimize weighted response time.
5. Minimize delay before a car is available for assignment.
6. Minimize travel distance for beatcar.
7. Maximum travel time for five minutes and similar workload per car (used in the Chicago 14th District experiment discussed later.).

Equalizing workload usually means determining a workload such as four calls/watch/car and then dividing total number of calls over a given period by four to determine the number of units needed. The current method of allocating personnel in the Chicago Police Department is a somewhat simplified version of O. W. Wilson's distribution method as developed in his book *Police Administration*.[16]

The objective function of his method is to equalize, as far as possible, weighted workload for each beatcar. The workload is a function of cells for service, required premise checks, and preventive patrol. Preventive Patrol is a function of misconduct hazards, assumed to be reflected in the volume of calls for service.

The total number of beats is determined by dividing the total number of calls for service (CFS) for the last identical season. This will provide the average daily number of CFS. It is assumed that four calls per watch per beatcar with one hour devoted to each call would be an appropriate workload, leaving "approximately four hours for preventive patrol during a tour of duty," counsels an official guide on assignment method.[17] Premise checks would be included in the preventive patrol time.

The total number of beats for three watches is arrived at by dividing average calls for service by four, as each beatcar handles four calls.

Weighted workload is calculated for each district by weighting calls for service as follows: Part I crime, 4; Part II crimes, 3; Other, 1. The weights are intended to reflect the seriousness and the service time required for the categories.

The number of district beats is determined by multiplying the district's share of citywide weighted workload (CWW) by the number of beats.

District beats = DB

$$DB = \frac{\text{District weighted workload}}{\text{CWW}} \times \text{No. of Beats}$$

This statistic is subjected to the following constraints:

1. The district weighted workload (DWW/CWW) ratio is compared with the District CFS/city-wide CFS ratio; if the difference is great, the reasons are determined with the object of maintaining a reasonable mix of Part I, Part II and Other calls for patrolmen.
2. Beats in a peripheral, residential district may become too large for adequate response time and preventive patrol; therefore, extra beats may be authorized.

Apportioning the number of district beats among the three watches is done by multiplying the Watch Weighted Workload (WWW/DWW) by the district's number of beats. The beat structure layout is developed for the third watch because it has the greatest relative workload. During the other two watches, when the total number of beats in service is reduced, each of the eliminated beats is covered by an adjacent car. In some districts (nine to be exact) overlapping watches called "powershifts," are used to match the actual demand for CFS more closely with available resources.

Lastly, the numbers of two-man and one-man car assignments are made. Attention is given to the number of incidents of resistance to police, multiple arrestees, deadly weapons involved and to geographical factors that affect easy access by neighboring squad cars. A ranked list is produced, showing are allocated subject to available manpower.

The criterion for judging a police system should, at least in part, be its impact on crime. It is not possible, at this state, to relate manpower allocation to criminal activity. One can, however, determine how well the system accommodates the functions of patrol with respect to the given objective function.

The present system is designed to equalize workload. Workload is defined as a function of calls for service, premise checks, and preventive patrol. The question we address: How well does the present distribution method achieve this objective? Three specific distributions were scrutinized: Between days of the week, Among watches and Between districts.

The week of August 16–August 22, 1968, was exhaustively investigated. The total amount of time spent on calls for service and on assist-calls was tabulated for each car.

Minutes spent on CFS for the third watch averaged 40 minutes per call. Assist-calls were approximately 10 minutes shorter. The number of CFS per beatcar per watch exceeded the target of four calls per car, in most instances.

Table 4–15

Percent of Calls for Service Answered by Beat Car

Day		16	17	18	19	20	21	22
By beat car	W1	23%	22	20	19	24	23	25
	W2	23	21	23	24	23	24	22
	W3	21	22	23	24	25	26	24
By nondistrict car	W1	13%	13	11	9	9	8	8
	W2	21	18	14	17	15	16	15
	W3	20	15	15	12	12	12	13

W1 = Watch 1 = 0001–0800 hours.
W2 = Watch 2 = 0801–1600 hours.
W3 = Watch 3 = 1601–2400 hours.

Assists, in many cases, amounted to one additional call per beat per watch. To be able to evaluate the time spend on the CFS and Assist function, a "utilization index" was defined.

Utilization Index = UI

$$UI = \frac{\text{Total time on CFS and Assists}}{\text{Total time on duty}} \times 100$$

This index was determined for both the whole system and the individual districts by watch. The desired utilization index (target index) of the present assignment system depends on the assumptions made. If four hours should be spent on CFS and Assists, and if total working hours is eight hours, then 50 percent represents the target index.

However one-half hour per shift is lost for lunch during the total eight hours, along with a usual two "personals" of 15 minutes each. Premise checks absorb approximately five minutes per beatcar per watch. Therefore the target index becomes 40 percent.

There exists, also, another time-consuming factor, travel time. The factor is calculated from the Time-out and Time-in stamp on the radio dispatch cards. The beat car still has to return to his beat if the assignment was outside his area. Only 23 percent of CFS are answered by the beatcar assigned to the beat-of-occurrence. A car outside the district will respond to approximately 13 percent of the CFS. (See Table 4-15)

Demand for police service fluctuates regularly with respect to the days of the week. Friday, Saturday and Sunday are the busiest days. Department policy, however, allocates an equal number of men to each week day. This demand pattern is shown in Table 4-16. The data here also reflect some discrepancies with respect to allocation on a system basis between watches. Most preventive patrol is performed in the early morning, probably when it is needed least.

Results of equal manning can be seen in the indices. Friday and Saturday, on a total system basis, exhibit a greater proportion of time spent on CFS. The difference is not great, and this should be expected from a system-wide point of view since many districts are residential. Table 4-16 also identifies a discrepancy in preventive patrol. The figures seem to show an allocation of 20–30–40 percent in the watches for weekdays, while the CFS workload is twice as large on the third watch.

The main criticism of the present allocation method must be levied against the objective, stated function.

Table 4–16

Total System Statistics

	Watch	Fri.	Sat.	Sun.	Mon.	Tues.	Wed.	Thur.
Utilization factors (in percent)	1	28	32	33	26	21	24	24
	2	43	34	28	34	30	33	31
	3	55	45	40	43	42	39	40
Calls for service answered by beat cars	1	1,151	1,232	1,408	925	860	1,013	898
	2	1,849	1,455	1,303	1,481	1,379	1,415	1,402
	3	2,616	2,356	2,031	2,158	2,279	2,123	2,205
Total		5,616	5,043	4,742	4,564	4,518	4,551	4,505
Assists answered by beat cars	1	348	207	303	280	220	258	263
	2	153	194	241	140	161	181	175
	3	272	362	428	314	290	321	311
Total		773	763	972	734	671	760	749
Average time (min.) per calls for service	1	44	43	40	46	41	39	43
	2	46	45	41	45	43	46	42
	3	43	40	41	42	38	39	38

The objective is equalizing workload, assuming that four CFS per beat car per watch is the goal. Even this limited coal is not achieved, as has been shown in the previous sections. Between districts, the utilization factors vary widely, as shown in Table 4-17. Only the third watch is shown because it has the highest workload; it is quite evident that Districts 2, 3, 5, 7, 10, 11 and 13 need more manpower during peak periods.

The more relevant objective of the department should be to minimize some function of response time and to maximize the probability of halting or preventing a crime through selective preventive or tactical patrol. This should determine the number of men in patrol and how they should be employed.

It has been shown that the actual time a patrol unit is available (counting lunch, personals, administrative and travel time as lost) is less than seven hours per watch. Table 4–15, above, supports the view that the beat car structure is only a good repositioning device and a very rough positioning tool. Soon after the beginning of the watch, the beat car will be off his beat, and the value of knowing a particular area becomes lost. "Magnetic beats" pull cars into their areas so that the density-space distribution of beat cars approximates the real demand.

It is perhaps evident from this discussion so far that very little preventive patrol is carried out at a time when it is needed most. For example, the Task Force, a flexible tactical unit, works from 1800-hours to 0200-hours. Indeed it seems that the beat car force is in practice responding only to CFS and doing minor premise checks. The Detective tactical units and the Task Force are responsible for tactical preventive patrol. When this state of affairs is realized, the step to deploying a Force A and a Force B to respectively carry out CFS and preventive patrol, as in St. Louis, becomes obvious. The current approach results in a waste of resources due to deficiencies in the assignment method and the difficulty of control.

The most serious problem is using an average figure for CFS per day for the system for a period of half a year. This is really too great an aggregation. Too much information which is relevant to the peaking of demands in the system is lost in the process. Even though the inclusion of assists will not change the system demands as between days, it does change the needs markedly for beat cars in specific districts.

Other deficiencies center around the critical assumptions made. The average service time is 40 minutes, not one hour. Calls for service per beat car is not representative of workload, as assists often amount to an additional call per watch per beatcar. The weights 4–3–1 are intended to reflect service time and seriousness of the call; instead, there is often an inverse relationship between seriousness of a crime and service time. A patrolman will write only a preliminary report on a homicide, leaving when detectives arrive. While on a burglary case, he would carry out a more thorough investigtion.

The workload criterion is a rough assignment guide. Optimally it results in an equal workload but in an unequal service level of CFS.

Further refinements are possible by using response time as a criterion. The appropriate analytical technique is queuing theory. The advantage is that it views demands for service and police response as a stochastic process, not an average as discussed previously. Thus the interrelationships of demand and service times are modeled so as to minimize response time. The queuing theory approach focuses on the availability of cars. To minimize response time, one seeks to minimize the expected average delay before a car is available for dispatch within a given sector.

Table 4–17

Utilization Indices for Third Watch (in Percent)

	August—						
	16	17	18	19	20	21	22
Districts:							
1........	71	31	26	27	31	28	27
2........	53	59	54	54	52	47	39
3........	53	63	42	44	48	45	45
4........	42	50	47	39	35	31	26
5........	62	60	41	41	51	43	40
6........	57	34	40	41	39	43	34
7........	58	63	44	49	52	46	49
8........	57	31	24	42	36	24	27
9........	41	23	29	32	25	31	37
10........	72	70	56	56	56	47	63
11........	57	52	52	55	46	48	44
12........	65	52	36	50	31	41	33
13........	73	52	40	43	45	54	48
14........	60	38	32	47	34	46	40
15........	56	40	33	50	41	33	42
16........	64	29	35	31	42	29	28
17........	50	36	53	40	46	31	45
18........	52	42	31	35	51	55	35
19........	37	31	40	49	41	34	42
20........	57	45	36	37	39	35	33
21........	45	31	34	22	30	32	30
System factors..	55	44	40	42	42	40	39

DESIGNING WITH QUEUING THEORY

A simple application of queuing theory was made, using a Poisson distribution for service calls, a negative exponential service time distribution and multiple parallel channels for service. Coupled to historical service call data, this application provided comparisons with current beat assignments.

The mathematical treatment is similar to the method employed by the St. Louis Resource Allocation Project[18] and described also by Larson in his work with the Boston Police Department.[1] Saaty provides a more detailed development of the queuing problem,[19,20] but the formulas are included here.

Distribution of the number of calls for service during a time interval is considered Poisson. A Poisson input follows from two assumptions:[19]

1. The total number of arrivals during any given time interval does not depend on the number of arrivals that occurred in the previous time interval.
2. In any interval $(t, t+dt)$, the probability that exactly one service call occurs is $\lambda dt+0(dt^2)$, where λ is a constant. The probability that more than one arrival will occur is of the order of dt^1 and may be neglected. λ represents the mean arrival rate (number of service calls per unit time) of service calls. Thus, $1/\lambda$ is the mean length of the time interval between two consecutive calls.

These assumptions seem proper, since callers are generally concerned with independent problems. The assumption breaks down when many people call at once about the same thing (tornado sighting, sonic booms, major fire or other disaster). More specifically, if the time intervals between calls are exponentially distributed, the input distribution is Poisson. Exponential distribution has a mean equal to its standard deviation. Both the call intervals and the car service times (the time difference between the Time Out and

Table 4–18

Service Time Data (0000–0800 Hours)
[Units are in minutes]

District	Mean	Standard deviation	Standard error	Range	Sample size
1	32.78	24.87	5.19	91.00	23
2	51.65	38.18	4.74	217.00	65
3	47.49	49.97	5.85	351.00	73
4	36.58	29.38	5.28	114.00	31
5	43.60	36.42	5.31	204.00	47
6	66.89	64.40	10.73	199.00	36
7	43.57	31.32	4.38	159.00	51
8	41.86	46.77	9.97	212.00	22
9	42.79	24.38	4.53	88.00	29
10	56.88	58.56	9.26	264.00	40
11	48.86	42.10	5.58	212.00	57
12	38.34	26.86	4.99	116.00	29
13	42.02	28.14	3.83	111.00	54
14	45.11	41.42	6.11	166.00	46
15	33.00	29.99	4.80	176.00	39
16	36.40	35.50	6.48	126.00	30
17	34.88	20.78	5.04	79.00	17
18	49.64	52.70	6.69	363.00	62
19	38.48	36.82	5.11	199.00	52
20	34.40	35.96	4.21	177.00	73
21	49.91	40.52	7.16	124.00	32

Table 4–19

Service Time Data (0800–1600 Hours)
[Units are in minutes]

District	Mean	Standard deviation	Standard error	Range	Sample size
1	46.58	51.32	6.05	351.00	72
2	54.81	45.87	3.96	283.00	134
3	45.59	34.36	3.19	171.00	116
4	42.11	32.34	4.72	144.00	47
5	41.99	34.26	3.61	189.00	90
6	29.07	21.93	2.62	136.00	70
7	39.91	25.31	2.29	132.00	122
8	49.52	48.01	6.25	283.00	59
9	38.28	36.74	4.39	211.00	70
10	47.90	33.56	3.56	192.00	89
11	39.87	29.25	3.03	177.00	93
12	54.27	48.75	5.05	362.00	93
13	39.21	28.91	3.04	148.00	90
14	40.86	29.78	3.21	156.00	86
15	41.28	51.76	5.72	274.00	82
16	41.34	39.42	5.01	241.00	62
17	41.40	35.78	4.82	224.00	55
18	40.81	33.90	3.39	212.00	100
19	37.10	32.56	3.31	172.00	97
20	36.53	37.02	3.42	252.00	117
21	43.88	53.43	6.17	404.00	75

Table 4–20

Service Time Data (1600–2400 Hours)
[Units are in minutes]

District	Mean	Standard deviation	Standard error	Range	Sample size
1	44.62	37.52	4.55	210.00	68
2	46.95	33.46	2.24	207.00	224
3	41.75	34.25	2.48	237.00	190
4	39.17	39.59	4.37	247.00	82
5	44.52	37.88	3.21	242.00	139
6	30.96	31.59	3.29	136.00	92
7	42.65	34.16	2.89	249.00	140
8	31.59	29.08	2.91	163.00	100
9	33.88	34.43	2.85	273.00	146
10	45.43	30.62	2.87	146.00	114
11	32.83	21.62	1.74	111.00	154
12	41.17	33.60	3.38	240.00	99
13	32.78	28.30	2.44	167.00	135
14	33.85	31.41	2.63	207.00	143
15	31.15	31.30	2.97	215.00	111
16	39.20	32.06	3.73	175.00	74
17	44.81	47.05	5.43	306.00	75
18	38.22	38.84	3.17	269.00	150
19	30.14	26.16	2.11	236.00	154
20	33.87	31.02	2.27	211.00	187
21	42.67	35.45	2.95	254.00	144

Time In stamped on the Radio Dispatch card) were listed for all districts. From this information, the means and standard deviations were computed. In nearly every case shown, the standard deviation and the mean were close in value. (Tables 4–18, 4–19, 4–20). Therefore, the assumptions of Poisson input and negative exponential service times for most Chicago Police Districts seemed proper. The validity of this hypothesis shows even more precisely when Chi-square test was applied. (Table 4–21)

In the current beat system, an adjoining beat car will answer a call on another beat if the officer on that beat is busy. From the point of view used in queuing theory, each district is comprised of "c" parallel channels servicing all of a district's calls. Thus c represents the number of beat cars. The notation used in the following Poisson formulas is given below, from Saaty[19,20].

λ = mean arrival rate (number of calls per unit time)

μ = mean service rate per channel—is the mean time difference between Time Out and Time In on the RD card)

c = numbers of cars for answering calls

n = number of calls in the district system

ρ = utilization factor for the district; $\rho = \lambda/c\mu$

Table 4–21

Test for Exponential Service Time Distribution by District
[For 17 degrees of freedom]

District	Average service time (hours)	χ^2
1	.70	31.1
2	.70	113.0
3	.66	67.1
4	.55	30.8
5	.57	76.8
6	.57	47.1
7	.67	78.0
8	.56	48.1
9	.52	41.3
10	.65	111.6
11	.68	73.2
12	.60	60.6
13	.58	51.0
14	.56	32.7
15	.53	40.6
16	.60	37.1
17	.57	39.0
18	.66	52.4
19	.56	36.6
20	.57	60.3
21	.67	36.1

$P\eta$ = the steady state (time independent) probability that there are n calls in the district, both receiving service and waiting for a service car

$P(0)$ = the probability of no waiting

$P(>0)$ = the probability of any waiting

$P(>\tau)$ = the probability of waiting greater than time τ.

Lq = the average number of calls in the queue awaiting service

W = the average waiting time in the system.

Mathematical Formulae

Under the condition that $\rho<1$, the following formula gives the probability that no calls are receiving service or waiting for service:

$$p_o = \frac{1}{\sum_{n=o}^{c-1} \frac{(c\rho)^n}{n!} + \frac{(c\rho)^c}{c!(1-\rho)}} \qquad (1)$$

and the number of calls waiting for an available car is

$$Lq = \frac{\rho(c\rho)^c}{c!(1-\rho)^2} p_o \qquad (2)$$

The other formulas which give the probability of a delay in finding an available car,

$$P(>0) = \frac{(c\rho)^c}{c!(1-\rho)} p_o \qquad (3)$$

the probability of a delay greater than τ,

$$P(>\tau) = \exp\left[-c\mu\tau(1-\rho)\right] P(>0) \qquad (4)$$

and the expected waiting time (excluding the waiting time in service)

$$W = Lq/\lambda \qquad (5)$$

are listed for future use. The St. Louis Project used equation (3) to give the estimated number of calls serviced with a delay.

One of the next steps concerns a priority discipline in the queue. In this case, more urgent calls (Priority 1) are taken on a first-come, first-served basis before calls of a lower priority.

As an example, this paper compares the expected waiting times for a no-priority and a two-priority system when .3, .5 and .7 of the total calls are considered Priority 1. In this case,

λ_1 = the mean arrival rate of Priority 1 calls

λ_2 = the mean arrival rate of Priority 2 calls

and

$$\sum_{k=1}^{2} \lambda_i = \lambda \qquad (6)$$

Assuming the same mean service time, $1/\mu$, for each car and each priority call, the expected waiting time for the kth priority is

$$W_k = \frac{\pi/c\mu}{\left(1-\frac{1}{c\mu}\sum_{i=1}^{k-1}\lambda_i\right)\left(1-\frac{1}{c\mu}\sum_{i=1}^{k}\lambda_i\right)} \qquad (7)$$

where

$$\pi = \frac{(\lambda/\mu)^c}{c!(1-\lambda/c\mu)\left[\sum_{j=0}^{c-1}\frac{(\lambda/\mu)^j}{j!} + \sum_{j=c}^{\infty}\frac{(\lambda/\mu)^j}{c!c^{j-c}}\right]} \qquad (8)$$

The last term in the denominator of equation (8) can be approximated as

$$\lim_{j\to\infty}\sum_{j=c}^{\infty}\frac{(\lambda/\mu)^j}{c!c^{j-c}} = \frac{(\lambda/\mu)^c}{c!}\lim_{j\to\infty}\sum_{j=0}^{\infty}\frac{(\lambda/\mu)^j}{c^j} \qquad (9)$$

$$= \frac{(\lambda/\mu)^c}{c!(1-\rho)}$$

so that equation (8) becomes

$$\pi = \frac{(\lambda/\mu)^c}{c!(1-\rho)\sum_{j=0}^{c-1}\frac{(\lambda/\mu)^j}{j!} + (\lambda/\mu)^c} \qquad (10)$$

$$\text{where } \rho = \frac{\lambda}{c\mu}.$$

The condition of $\rho=\lambda/c\mu<1$ is relaxed in the priority system to

$$(1/\mu c)\sum_{k=1}^{p}\lambda_k < 1 \qquad (11)$$

for the pth priority. In other words, $\lambda 1/\mu c<1$ for computing the Priority (1) case is a less demanding condition than $\lambda/\mu c<1$.

Computational Method

Equations (10) and (7) were used to compute the expected waiting times with the condition of equation (11). Past calls for service by hour for a particular day in the 3rd and 14th Districts were used in the first rest. The total calls for the 1st, 2nd, and 3rd watches were divided by (8×60) minutes to determine

Table 4–22

Third District (λ = 0.442; $1/\mu$ = 20 Minutes) 30 Percent Priority I Calls

Priority I coefficient	Average wait (min.) priority I	Average wait, priority II*	Cars service time (min.)
.30	332.21	−170.65	3
.30	67.47	−55.76	4
.30	29.82	−38.84	5
.30	15.72	−33.22	6
.30	8.86	−33.70	7
.30	5.11	−48.71	8
.30	2.95	166.49	9
.30	1.69	14.60	10
.30	.94	4.83	11
.30	.51	1.96	12
.30	.27	.85	13
.30	.13	.37	14

*Minus sign indicates an infinite queue is forming, or insufficient cars to answer prioroty (II) calls.

λ, the calls per minute. While the mean service times, $1/\mu$ for each district were known from historical data, this time was varied from 20 minutes to 50 minutes in 10 minute increments to test the sensitivity of the number of beat cars required to provide the same levels of service.

The number of Priority 1 calls, $\lambda/$, was derived from λ by multiplying with the coefficients 0.3, 0.5, 0.7, and 1.0. In effect, these coefficients cover circumstances where 30 percent, 50 percent, 70 percent and

Table 4–23

Third District (λ = 0.442; $1/\mu$ = 30 Minutes) 30 Percent Priority I Calls

Priority I coefficient	Average wait (min.), priority I	Average wait, priority II*	Cars service time (min.)
.30	1552.72	−4990.37	4
.30	210.04	−127.14	5
.30	88.63	−73.25	6
.30	48.89	−54.67	7
.30	29.85	−45.41	8
.30	19.13	−40.42	9
.30	12.55	−38.50	10
.30	8.30	−40.43	11
.30	5.49	−52.35	12
.30	3.61	−180.58	13
.30	2.34	44.34	14
.30	1.49	12.89	15
.30	.93	5.46	16
.30	.57	2.60	17
.30	.34	1.29	18
.30	.19	.65	19
.30	.11	.33	20

*Minus sign indicates an infinite queue is forming, or insufficient cars to answer priority II calls.

all calls are treated as Priority 1 calls. As a matter of interest, the number of calls received by the police, and this includes all traffic accidents, were analyzed, and it was found that Index Crimes (murder, rape, serious assault, robbery, burglary, theft over $50 and auto theft) and non-Index Crimes accounted for less than 30 percent of the beat car dispatches.

As shown in the following tables (4–22, 4–23), the priority system does not offer a major saving in beat cars if Priority-I calls receive service without any waiting. (For the tables, a no-waiting service level was defined as a 10-second mean waiting time. The tables also show that Priority-II calls exceeded by a factor of three the mean waiting time of the Priority-I calls. However this waiting time amounted to 30 seconds.

The results of the high service level case indicate that the priority system offers a saving of perhaps one car over the case of all calls receiving a high service level (low mean waiting time). Notice, however, the case when forces are reduced. In these cases, for λ_1, equal to different percentages of λ, the Priority I calls can receive an available car in less than a minute, while the Priority II calls wait longer. Thus when the normal forces of a district are reduced because of a mobilization for civil disorder, an emergency plan or for any other reason, a switch to the two-priority system offers a means of maintaining service on important calls. It also offers a means of predicting the waiting period for less important calls as a function of the cars available.

The tables also show, above and in Tables 4–24 through 4–29, below, the importance of a low mean service time, $1/\mu$.

In some cases, an average reduction in the mean service time of 10 minutes will provide a saving of six cars to the district on a particular watch. While the priority system will save cars under adverse conditions, the greatest overall savings will result from decreased service times, or of course, a decrease in the number of calls receiving squad car service. These effects are summarized graphically by Figure 4–10.

Table 4–24

Third District (λ = 0.442; $1/\mu$ = 40 Minutes) 30 Percent Priority I Calls

Priority I coefficient	Average wait (min.) priority I	Average wait, priority II*	Cars service time (min.)
.30	562.13	−288.77	6
.30	200.99	−131.73	7
.30	109.30	−90.33	8
.30	68.33	−70.85	9
.30	45.66	−59.45	10
.30	31.63	−52.09	11
.30	22.36	−47.24	12
.30	15.97	−44.36	13
.30	11.44	−43.54	14
.30	8.19	−45.86	15
.30	5.83	−55.57	16
.30	4.12	−103.01	17
.30	2.87	161.84	18
.30	1.98	28.52	19
.30	1.34	11.58	20
.30	.89	5.65	21
.30	.58	2.97	22
.30	.37	1.61	23
.30	.23	.88	24
.30	.14	.48	25

*Minus sign indicates an infinite queue is forming, or insufficient cars to answer priority II calls.

Table 4–25

Third District (λ = 0.442; $1/\mu$ = 50 Minutes) 30 Percent Priority I Calls

Priority I coefficient	Average wait (min.) priority I	Average wait, priority II*	Cars service time (min.)
.30	1677.67	−777.72	7
.30	405.29	−229.95	8
.30	208.45	−143.21	9
.30	129.68	−107.17	10
.30	87.92	−87.13	11
.30	62.47	−74.23	12
.30	45.65	−65.22	13
.30	33.93	−58.65	14
.30	25.47	−53.82	15
.30	19.22	−50.42	16
.30	14.52	−48.41	17
.30	10.95	−48.10	18
.30	8.23	−50.44	19
.30	6.14	−58.52	20
.30	4.55	−86.86	21
.30	3.33	−733.92	22
.30	2.41	61.78	23
.30	1.72	21.84	24
.30	1.21	10.50	25
.30	.84	5.63	26
.30	.57	3.17	27
.30	.38	1.83	28
.30	.25	1.06	29
.30	.16	.62	30
.30	.10	.35	31

*Negative sign indicates an infinite queue is forming, or insufficient cars to answer priority II calls.

Table 4–26

Third District (λ = 0.442; $1/\mu$ = 20 Minutes) 100 Percent Priority I Calls

[All calls taken on a first-come, first-served basis]

Priority I coefficient	Average wait (min.) priority I	Cars service time (min.)
1.00	117.43	9
1.00	10.72	10
1.00	3.67	11
1.00	1.53	12
1.00	.68	13
1.00	.30	14
1.00	.13	15

Table 4–27

Third District (λ = 0.442; $1/\mu$ = 30 Minutes) 100 Percent Priority I Calls

[All calls taken on a first-come, first-served basis]

Priority I coefficient	Average wait (min.) priority I	Cars service time (min.)
1.00	31.74	14
1.00	9.47	15
1.00	4.10	16
1.00	1.99	17
1.00	1.00	18
1.00	.51	19
1.00	.26	20
1.00	.13	21

Current Beat Comparisons

The direct use of the queuing analysis in place of the current method of beat car assignment will require more work. Briefly, the current system attempts to devote half the time of each beat car to preventive patrol. The beat car driver spends 30 minutes in roll call and eight hours on the street. Normally each beat car is allowed another 30 minutes for a meal during its watch. A review of lunch cards, administrative cards, premise check cards, and car service cards for District 3 and District 14 during a 24-hour period on 3 September 1968 showed an overall average of nearly two hours out of the beat system for every car on each watch.

Table 4–28

Third District (λ = 0.442; $1/\mu$ = 40 Minutes) 100 Percent Priority I Calls

[All calls taken on a first-come, first-served basis]

Priority I coefficient	Average wait (min.) priority I	Cars service time (min.)
1.00	114.15	18
1.00	20.56	19
1.00	8.51	20
1.00	4.22	21
1.00	2.25	22
1.00	1.24	23
1.00	.69	24
1.00	.38	25
1.00	.21	26
1.00	.11	27

Table 4–29

Third District (λ = 0.442; $1/\mu$ = 50 Minutes) 100 Percent Priority I Calls

[All calls taken on a first-come, first-served basis]

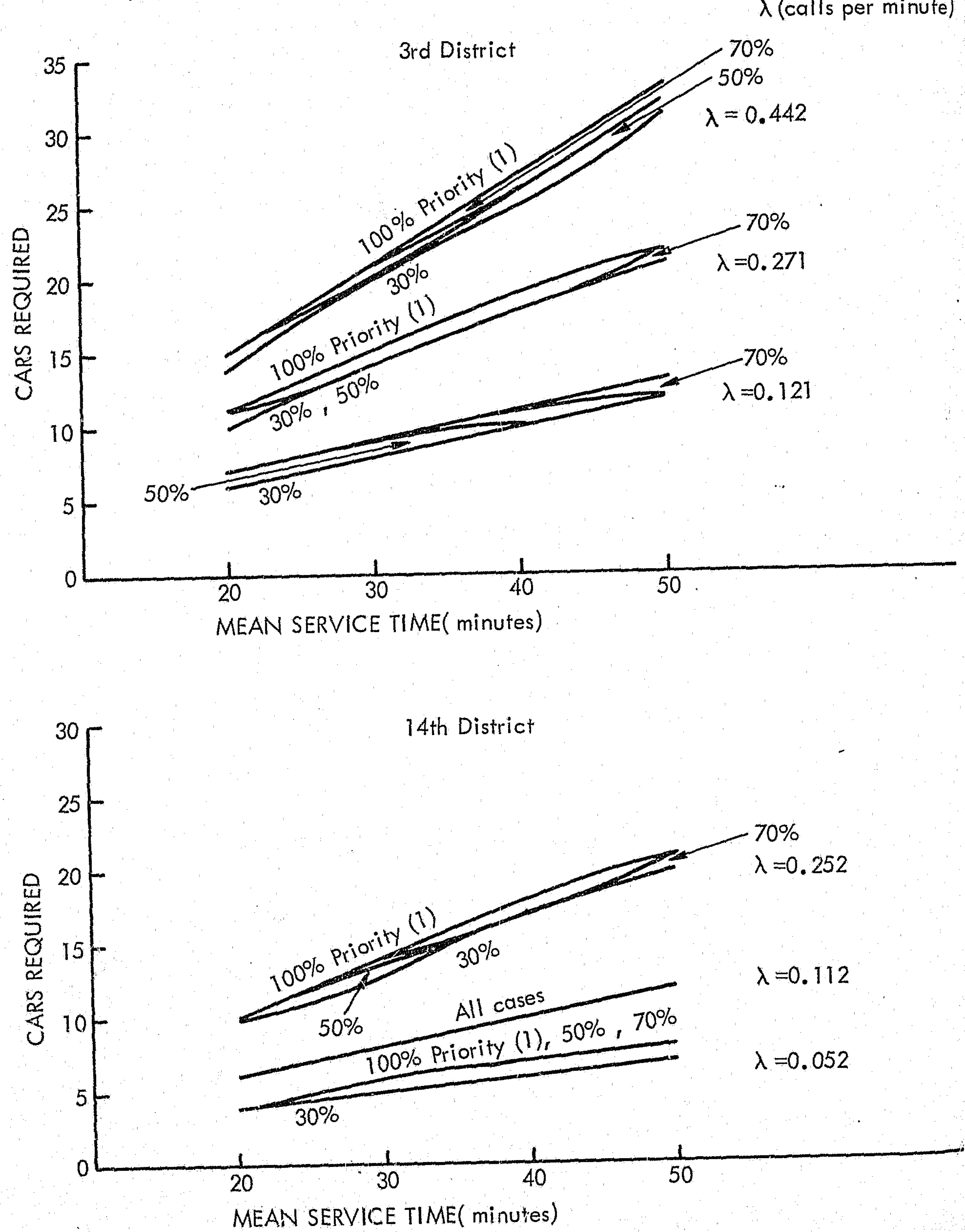
Priority I coefficient	Average wait (min.) priority I	Cars service time (min.)
1.00	43.97	23
1.00	15.80	24
1.00	7.72	25
1.00	4.20	26
1.00	2.39	27
1.00	1.39	28
1.00	.82	29
1.00	.48	30
1.00	.28	31
1.00	.16	32
1.00	.09	33

In District 3, the 22 premise checks made in the period took a total of five hours and 10 minutes. In addition, one beat car was detailed to one location for nearly 10 hours. Another was detailed for a period of six hours and 28 minutes. By comparison to the various types of administrative cards and car service cards, the time off the air for premise checks was very slight. The time spent on premise checks and some traffic violation stops is consistent with the goals of preventive patrol. So this time cannot be considered lost from preventive patrol time.

Clearly, the average time of two hours subtracted from eight hours of watch time leaves only about six hours to answer calls for service. (The average time per beat car spent on premise checks only adds back five or 10 minutes.) The mean service time for calls in District 3 runs about 50 minutes. Since the number of beat cars assigned to each district assumes answering four calls per watch, only two hours and 40 minutes remain throughout the watch for preventive patrol. Currently, many districts average more than four calls per car per watch. In addition, most of a car's calls occur off the assigned beat. Since the car usually returns to its beat in the most expeditious manner, this travel time further detracts from the available time and effective conduct of preventive patrol. Effective preventive patrol requires the car to patrol areas of high criminal opportunity or high criminal activity. The mere sight of a police car proceeding down the street would seldom, in itself, deter a criminal act unless revisits were frequent and random.

In the preceding, averages were used. An actual day in District 14 showed 2.5, 4.5, and 6.4 calls per car for the first, second and third watches respectively. In this case, a great deal of time was available for

Figure 4-10 : Cars Required to Insure An Available Car for all Priority (1) calls within (10) seconds



preventive patrol from midnight to 0800, less from 0800 to 1600 and very little from 1600 to 2400 hours. How the cars were actually assigned is shown in Table 4–30 (Winter) and Table 4–31 (Summer).

These are the most recent beat assignments by watch and district.

Since the time of occurrence and the length of time a car is out of service are needed to construct a complete queuing model, the effects of administrative cards, car service cards, lunch cards and premise checks cannot be neglected in either an analytic computation or computer simulation of the beat car allocation problem.

Currently, the four categories of cards are not keypunched for data processing. Only those cards which indicate the dispatch of a beat car to a complaint call are keypunched and recorded on computer tape. Therefore, the queuing model must rely solely upon the Radio Dispatch (RD) cards to establish the working force level. If Chicago adopted a split force (one force for answering calls, another to conduct preventive patrol) the time-outs for premise checks and some of the traffic violations could be handled by the preventive patrol force. The fact remains, however, that these categories represent very little of the time-out for the beat cars. Before the actual implementation of a queuing analysis for beat car allocation, more study of these categories will be undertaken.

Table 4–30

Number of Beat Cars Assigned Each District From November 1967 to May 1968

	0000–0200	0200–0800	0800–1000	1000–1600	1600–1800	1800–2400
Watches	1	1	2	2	3	3
District:						
1	7	7	13	13	11	11
2*	27	15	15	27	30	30
3*	28	17	17	28	31	31
4	13	13	13	13	†13/5	†13/5
5	11	11	15	15	18	18
6	14	14	14	14	14/4	†14/4
7*	23	14	14	22	26	27
8	15	15	†15/1	†15/1	†15/4	†15/4
9	12	12	16	16	19	19
10*	20	13	13	20	23	23
11*	23	16	16	23	26	26
12	10	10	15	15	16	16
13	12	12	18	18	23	23
14	10	10	16	16	19	19
15	9	9	17	17	18	18
16	9	9	11	11	11	11
17	9	9	13	13	13	13
18*	21	13	13	21	22	22
19	15	15	22	22	25/5	25/5
20	21	14	14	21	25	25
21	19	19	19/2	19/2	19/5	19/5

* Power beats.
† Saturation/beat cars.

Table 4–31

Number of Beat Cars Assigned Each District From May 1968 to November 1968

	0000–0200	0200–0800	0800–1000	1000–1600	1600–1800	1800–2400
Watches	1	1	2	*2	3	*3
District:						
1	7	7	13	13	11	11
2*	29	16	16	27	27	29
3*	26	15	15	26	27	27
4	13	13	15	15	† 15/5	† 15/5
5	10	10	15	15	17	17
6	15	15	15	15	† 15/4	† 15/4
7*	22	15	15	22	20	27
8	15	15	15	15	† 15/4	† 15/4
9	11	11	16	16	20	20
10*	22	12	12	22	24	24
11*	24	14	14	24	25	25
12	10	10	16	16	16	16
13	13	13	19	19	23	23
14	10	10	16	16	20	20
15	9	9	16	16	18	18
16	9	9	10	10	11	11
17	9	9	12	12	12	12
18*	21	13	13	21	22	22
19	14	14	24	24	† 25/5	† 25/5
20	27	16	16	27	30	30
21	23	23	† 23/1	† 23/1	† 23/7	† 23/7

* Power beats.
† Saturation/beat cars.

Notes on Queuing Approach

Richard Larson[1] uses a weighted response time criterion. He assumes interdistrict dispatching and minimizes travel time. His model will be discussed later.

The difficulty with the queuing theory applications lie with the assumptions that have to be made to make the mathematical models tractable. Larson showed that for Boston[21] the assumption of Poisson input was a good approximation. In most cases the Chi-square test for the Poisson hypothesis was significant at the 5 percent level. His exponential service times did not fit the real world data very well. In Chicago both empirical distributions are significantly different from their theoretical equivalents (Table 4–21 above).

How should a response force be positioned, and what assignment rules should be used for selecting a car to service a call? There exist no models for evaluating the initial positioning of police units once the sector assignment has been made. The beat structure provides a rough positioning tool.

The assignment decision is usually left to the individual dispatcher. Most often, with a beat car structure, it entails a center of mass dispatching strategy. This means that if the beat car is not busy, he is assumed to be positioned at the center of his beat. This is erroneous, of course, but no other information is available with a beat structure. There are other complications. For administrative reasons, interdistrict dispatching is not allowed except for emergencies or if a district is out of cars. Another difficulty is the judgment of the number of men/cars to send in on a call.

Organizational variables are a very important factor of system efficiency. Due to the nature of police work, it is very difficult to maintain effective supervision. In New York, for example, *The New York Times* reported that some policemen were found sleeping in their cars during the first watch. If supervision is lacking, service times tend to increase, and the availability of cars decreases. Most queues are very sensitive to the service time variable. It was found that a 10-minute decrease in service time amounted to a saving of six cars out of 30 assigned to a district.[22]

THE LARSON MODEL

The Larson model is still the state of the art with respect to field response models. It is an analytical model which determines the mean value and the density function of the response time distribution. The model development is too long for presentation here, but its assumptions[23] and results are worth detailing:

1. Patrol sector geometry is described by a rectangular grid or equidistant streets.
2. The positions of patrol and the incident are statistically independent.
3. All points on the grid are equally probable.
4. The patrol car follows a shortest route to the scene of the reported incident.
5. A patrol car is available to service a call with probability ≥ 0.3.
6. The city is large enough so that no queue of dispatches ever forms.
7. The dispatcher uses a "closest-center-of-mass" dispatching strategy since the exact positions of the patrol units are either not known or not considered.
8. The expected travel time is equal to a "start-up time" and expected travel distance divided by the speed of the vehicle.

The first assumption was necessary because the model was developed for Boston which is known for its absence of a rectangular street grid. The next assumption permits him to ignore the deterrence effect of police presence on calls for service. The third assumption is a convenient one, and he shows that his result is insensitive to it. Larson assumes an availability of cars greater or equal to 0.3; this assumption implies that at least one car is always available in one of the four adjacent beats.

Assumptions Six and Seven imply that interdistrict dispatching is permitted, and no stacking of calls is allowed. The dispatching strategy is the same as the one used in Chicago. If a car is available, he is assumed to be in the center of his beat. This is not true, of course. The police officer may decide that an adjacent beat warrants more preventive patrol than his own. In addition, when returning back to his beat after assignment to another beat, it is physically impossible for the assumption to be true. This is probably the most crucial assumption and involves the organizational variables of the system.

Lastly, to use a continuous approximation to his originally derived discreet formulation of expected travel distance function, he adds a constant term called "start-up" time. It can also be used as a linear factor when fitting the curve to real data.

For the expected travel time Larson gets:

$$E_{tt} = t_s + \frac{2}{3 \cdot S}\sqrt{\frac{A}{K}}\,(2-\rho)$$

where:

tt = travel time
t_s = start-up time
S = speed
A = area for which cars are dispatched
K = number of police units
ρ = availability

Larson also derives an expression for the density function of the response time distribution.

$$f_{d_r}(d) = P_r(E_1) f_{d_r}/E_1(d/E_1) + \sum_{k=1}^{\infty} P_r[E_{2k}] f_{d_r}/E_{2k}(d)E_{2k}$$

$$+ \sum_{l=2}^{\infty} P_r[E_3] f_{d_r}/E_{3l}(d/E_{3l})$$

where

$$P_r(E_1) = \rho$$

$$P_r(E_{2k}) = (1-\rho)^{2k(k+1)-3}(1-(1-\rho)^4) \qquad k = 1, 2, \ldots$$

$$P_r(E_{3l}) = (1-\rho)^{2l^2-2l+1}(1-(1-\rho)^{4l-4}) \qquad l = 2, 3, \ldots$$

There are essentially three different cases we must consider to derive the probability density function of d_r:

E_1—Patrol car (0,0) assigned to service the call
E_2—A patrol car $(0,i)$ or $i;0)$ assigned to service the call (i—non-zero integer)
E_{3ij}—A patrol car (i,j) assigned to service the call (i,j—non-zero integers).

He shows that:

$$f_{d_r/E_1}(d/E_1) = \begin{cases} 4d - 4d^2 + 3d^3 & 0 \leq d \leq 1 \\ 16/3 - 8d + 4d^2 - 2d^3/3 & 1 \leq d \leq 2 \\ 0 & \text{otherwise} \end{cases}$$

$$f_{d_r/E_{2i}}(d'/E_{2i}) = \begin{cases} d'^2 - d'^3/3 & |i|-1 \leq d \leq |i| \\ 2d'^3/3 - 4d'^2 + 7d' - 3 & |i| \leq d \leq |i|+1 \\ -d'^3/3 + 3d'^2 - 9d' + 9 & |i|+1 \leq d \leq |i|+2 \\ 0 & \text{otherwise} \end{cases}$$

where $d' = d - |i|$

$$f_{d_r/E_{3ij}}(d'/E_{3ij}) = \begin{cases} d'^3/6 & |i|+|j|-2 \leq d \leq |i|+|j|-1 \\ (-3d'^3 + 12d'^2 - 12d' + 4)/6 & |i|+|j|-1 \leq d \leq |i|+|j| \\ (3d'^3 - 24d'^2 + 60d' - 44)/6 & |i|+|j| \leq d \leq |i|+|j|+1 \\ 9 - d'^3 + 12d'^2 - 48d' + 64)/6 & |i|+|j|+1 \leq d \leq |i|+|j|+2 \\ 0 & \text{otherwise} \end{cases}$$

where

$d' = d - |i| - |j|$

d = travel distance in terms of sector lengths

To fit his functions to Boston data, Larson was forced to assume a multiplicative delay factor. In effect, he is reducing the average speed at which the police unit is responding to a call for service. This is realistic because if a car is not on his beat, where he should be, the travel distance will be longer, or to fit the model, the effective travel time would be longer.

The only response time data available at the Chicago Police Department was collected for an experiment conducted in the 14th District. As the Larson model assumes interdistrict dispatching over the area concerned, although not the dispatch policy in Chicago, it would be logical to apply it to a single district.

Interdistrict dispatching in Chicago is allowed only for emergencies and when the district is out of cars. Checking Radio Dispatch tapes revealed that 20 per cent of all calls for service in a district are answered by a non-district car.

The Larson model was fitted to the response curve shown in Figure 4-11. The best fit (lowest Chi-square value) occurred at a speed of 12 mph and an availability of 40 per cent. The Chi-square value of 42.28 for nine degrees of freedom indicates a high probability of an alternative response curve. Likely this is due to two factors: The 20 per cent of interdistrict dispatching which does not permit viewing the 14th District as a self-contained area and to the fact that the availability function is violated; on a Friday night availability drops below 0.3.

CHICAGO SIMULATION MODELS

We have seen that the Larson model does not exhibit a close fit with Chicago data. The model is very restricted, evaluating only a very limited set of alternatives. However, the application of a simulation approach is ideal. In the real world, many experiments are very difficult to carry out, partly because of undesirable ill effects if the experiment fails and partly because to the difficulty in collecting data on system performance. A simulation model thus becomes a very convenient tool when evaluating a large set of alternatives. Once the better alternatives have been determined, they can be tested in the real world.

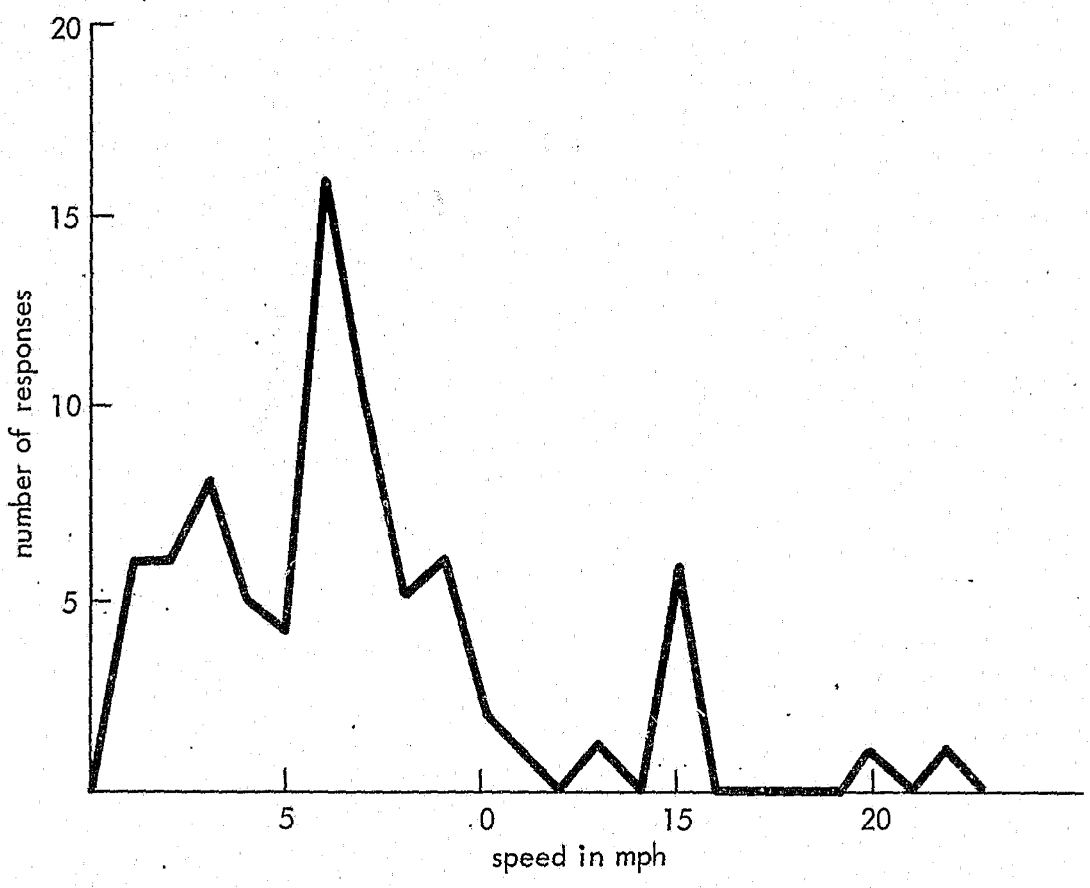
A model should permit evaluation of:

1. Demands for service in space/time (i.e. stacking).
2. Positioning of forces in space time (i.e. beat structure).
3. Assignment rules (i.e. center of mass versus car locator system, interdistrict dispatching).
4. Organizational variables (for example a decrease in service time, more on-beat patrol, less car down time for repairs on the third shift, etc.).

The simulation model used here has a modular structure developed to accommodate all of the above alternatives.

What outputs are desired from the model? The model should permit an evaluation of the center of mass and the use of car locator dispatching strategies for different alternatives. By a car locator strategy, we mean the existence of a system that will provide the dispatcher with actual car positions; the closest car is chosen under the assignment rules. The evaluation of the benefits of a car locator system is im-

Figure 4-11 : Response Speed Distribution , 74 observations.
(Mean: 6.6 mph, standard deviation 4.78)



portant because it is a fashionable hardware item for police departments. The system represents a great commitment of resources, and its possible benefits are not too well understood.

Each output from the model includes response time distributions for both strategies for the alternative being evaluated. This has the advantage of facilitating comparison as all stochastic elements will have the same value. In addition, the travel distance saved by the car locator system is exhibited. For validation purposes, the model provides such operational information as:

1. Percentage of calls answered by beat car or district car respectively.
2. Average number of calls/car/district.
3. Minutes spent on calls for service and administration.
4. Number of car services, car repairs, lunches and personal breaks.

To judge system performance, we computed (a) average availability for the system as well as for the 14th District and (b) the probability of choosing the closest car using center-of-mass dispatching stretegy.

The scope of, the model has two dimensions: the number of districts and the set of activities to be included.

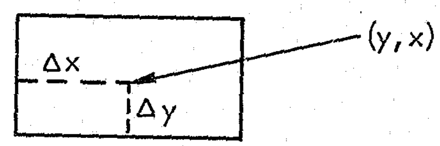
Focal point of the simulation model is the 14th District and its surrounding districts (eight in all). The reason for its selection was the availability of 14th District data as compared with the extreme difficulty of collecting data on other districts.

The scope of activities includes the handling of calls for service and administrative down-time. In addition, preventive patrol activities are modeled so that car position can be determined when the car is considered for assignment. It is convenient to include the extra waiting time in the dispatch queue as a result of stacking procedures. Screening is easily handled by reducing the exogenous events.

There are two types of entities in the system. The first is the beat car. Its 13 attributes are:

1. Reference point x.
2. Reference point y.
3. Delta x for rectangle specification.
4. Delta y for rectangle specification.
5. Number of officers in car.
6. Availability, 0=busy, 1=available, 2=not in service.
7. Car is 0=outside beat, 1=inside (uniform), 2=inside (constrained uniform).
8. Current location x.
9. Current location y.
10. District.
11. Beat.
12. Time of last computation of location.
13. Car lunch.

Attributes 1–4 define the beat. It is assumed to be rectangular. Reverence points x and y represent coordinates for locating the center-of-mass of the beat; Delta-x and Delta-y are the distances from the center to the beat boundaries.



The next attribute refers to how many men are assigned to the car. This is necessary as input to the car assignment subroutine. Availability provides information on car status. If equal to two, the car is not in service that evening. Attributes 7, 8, 9 and 12 are necessary for determining the position of available cars in the system. These will be discussed further in the positioning subroutine section. Attributes 10 and 11 permit the program to gather statistics on car performance and relate these to the administrative structure of district and beat numbers. The last item is a control variable to keep track of how many personals a car has had and if its crew has lunched. This is done conveniently through the following coding:

Personals

		No	Yes (1)	Yes (2)
Car	No	0	2	5
Lunch	Yes	1	3	4

Calls for service have the following attributes, shown as the Input Format of Exogenous Events:

1. Type of event radio dispatch 1–89.
2. Time-out.
3. Time-in.
4. Beat of occurrence.
5. Arrest: 1=arrest, 0=no arrest.
6. Quadrant.
7. X-location.
8. Y-location.
9. Day.
10. Number of cars.
11. Number of men needed (1, 2, 3, 4).

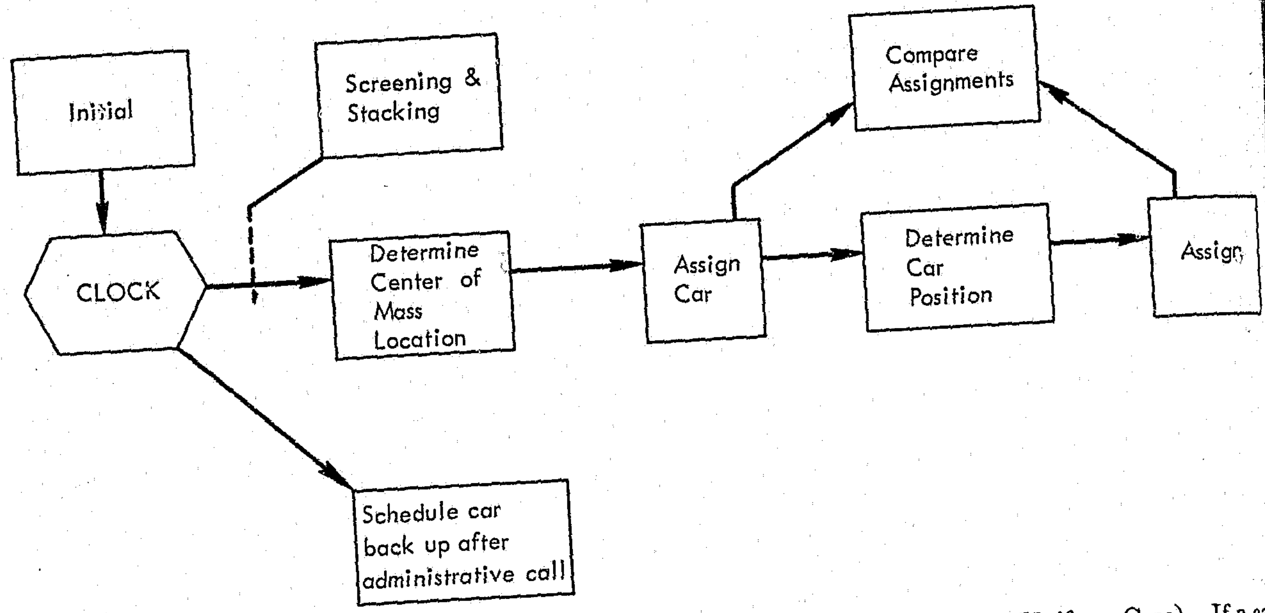
The type of event is based on the 13-category coding used by the Chicago Police Department for Index Crimes, miscellaneous noncriminal cases, etc. The time-out and time-in items schedule the event and provide the service time for handling the call. The arrest variable is necessary to take a car out of service when handling an arrest, usually 1.5 hours. The next three items determine the location of the event. The ninth item is included to permit simulation of more than one day at a time. The last two factors represent the actual number of cars and the number of men assigned to the call. This is used in the assignment routine to determine the number of cars to send in. The program's structure is diagrammed in Figure 4-12.

The initialization routine sets parameters, zeros out the necessary lists and reads in the car attributes. The advantage of this arrangement is that alternative positioning methods can be specified easily. The clock routine schedules the events, either calls for service or administrative calls. If the former, screening or stacking may be employed before the call is assigned to a car.

The subroutine assigns calls to the subroutine *Center* which generates the center-of-mass locations of all available cars in the system and ranks them on distance away from the event's location. The ranked list includes the distance, district, beat and manning for each available car.

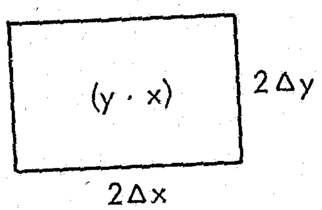
Assign next calls subroutine *Cars*. Given the number of men needed, *Cars* chooses one or more cars accord-

Figure 4-12 : Flowchart for Simulation Model of Field Response



ing to the assignment rule specified. To generate the actual travel distance for the assigned car, *Assign* calls *Position*, which generates the actual location of all available cars. This routine is really the heart of the whole simulation.

Assume a rectangular beat with its center at (x, y) and sides 2 Delta y and 2 Delta x.



$$xloc = Randin\ (x - \Delta x,\ x + \Delta x)$$

$$yloc = Randin\ (y - \Delta y,\ y + \Delta y)$$

Three main cases can be distinguished for generating a car's location.

Case I, (*The Uniform Case*)—If item 7 of the car attributes is equal to one, the car is patrolling inside his beat. His location can be determined by a drawing from a uniform distribution (Randin).

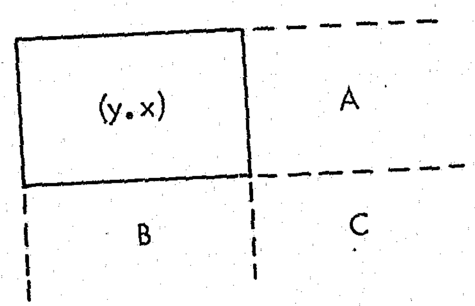
$$x\ loc = Randin\ (x - \Delta x,\ x + \Delta x)$$

$$y\ loc = Randin\ (y - \Delta y,\ y + \Delta y)$$

Case II, (The Constrained Uniform Case)—If a car is assigned to a call inside his beat, item 7 is set to 2, item 12 to the time when he comes back up, and items 8 and 9 to the coordinates of the event. Naturally the car's position after he becomes available is a function of the time that has passed since he came back up. His location can be generated by determining the union of the beat rectangle and a rectangle whose sides are equal to the time elapsed since his last location, times speed of travel. It is now possible to generate his location with a uniform distribution, as before.

Case III, (Outside beat)—The more difficult case appears when the car is assigned outside his beat. Item 7 of the car attributes is set=0. As before, the coordinates of the event are stored and the time entered in item 12.

Three distinct alternatives are apparent:



The car may be in the general direction of A, B or C. (The argument is symmetrical.) We assume

that the car returns by the shortest route to his beat and that there is a rectangular street grid.

Alternative I: From point A, the car will proceed along the same y-coordinate until the boundary of the beat is reached. If not enough time has elapsed to reach the beat boundary, his location will be $(x + \Delta time \times speed, y)$. If there is extra time, item 7 is set equal to 2, item 12 is set equal to the travel time needed to reach the boundary plus the original time, and transfer to Case II is made.

Alternative II: The same calculations are performed for the y-coordinate for an initial position of B.

Alternative III: For the third alternative C, some simplifying assumptions are made. The car is assumed to travel North/South or East/West until his extended beat boundary is reached; from there he follows the boundary to the beat corner. The initial direction is determined by a random function with a 50 per cent chance for either direction. As before, the distance to be covered is determined from the time and speed. When the car reaches the beat boundary, proper transfer is made to Case II.

After the actual locations of the cars have been determined, a ranked list, as before, is generated. The same assignment routine with the same assignment rules is called, although the cars are not actually assigned. The positions of the center-of-mass assigned cars are used to compare travel distances between the two strategies, since the actual locations of the center-of-mass dispatched cars are now known.

Administrative calls are events such as: Car service for gas; car repair (radio, tires, engine); personals and lunch.

The initialization routine takes 25 per cent of the cars out of service, as soon as the watch begins, to fill gas tanks. The rest of the car service calls are taken during the watch. When each car becomes available after a call for service or administration, a uniform random number between 1 and 60 is drawn to determine when the car should try to take a personal, lunch or car service break.

Distribution of lunches as a function of time were used to determine cumulative probability functions for taking a car out of service. (Figure 4-13)

Figure 4-13 : Distribution of Lunches for 24 Hours

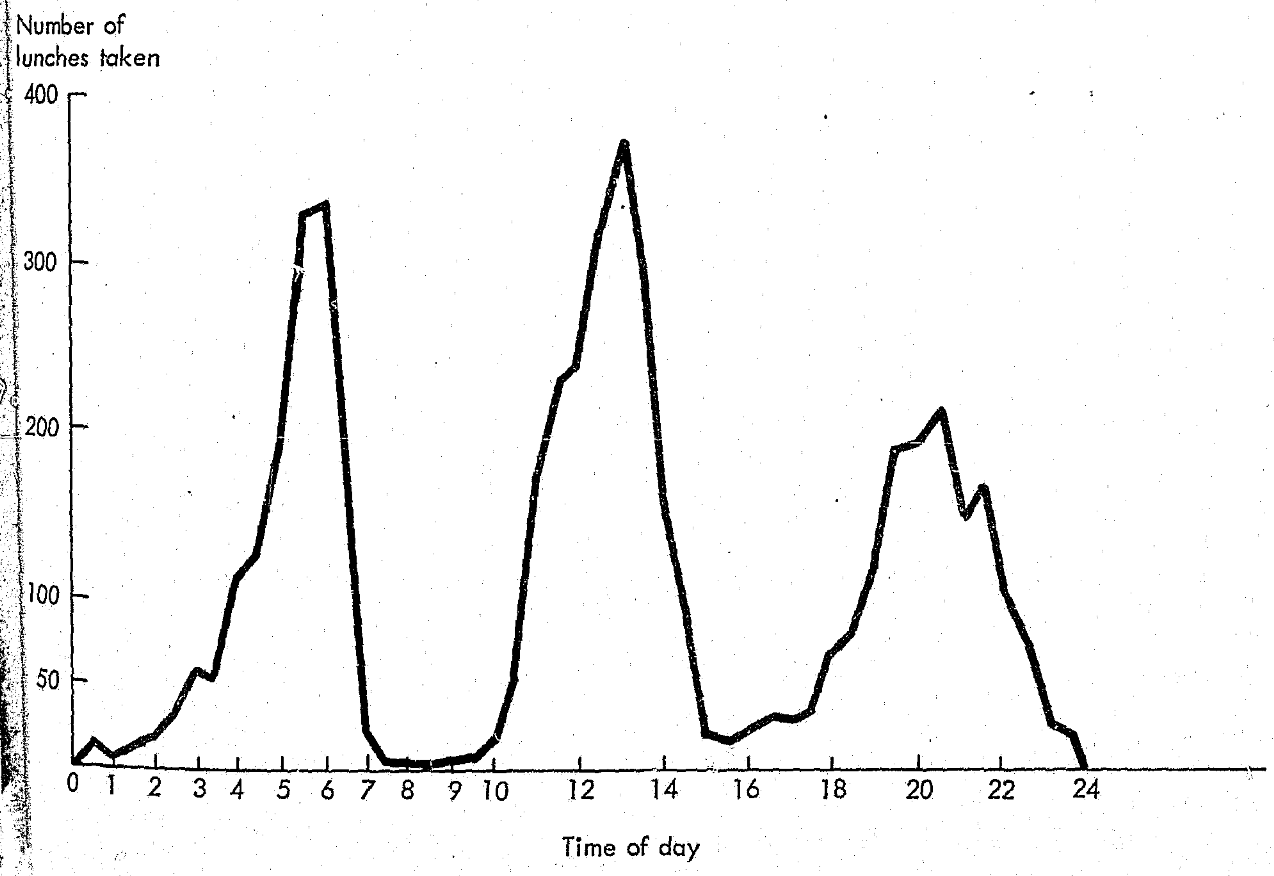
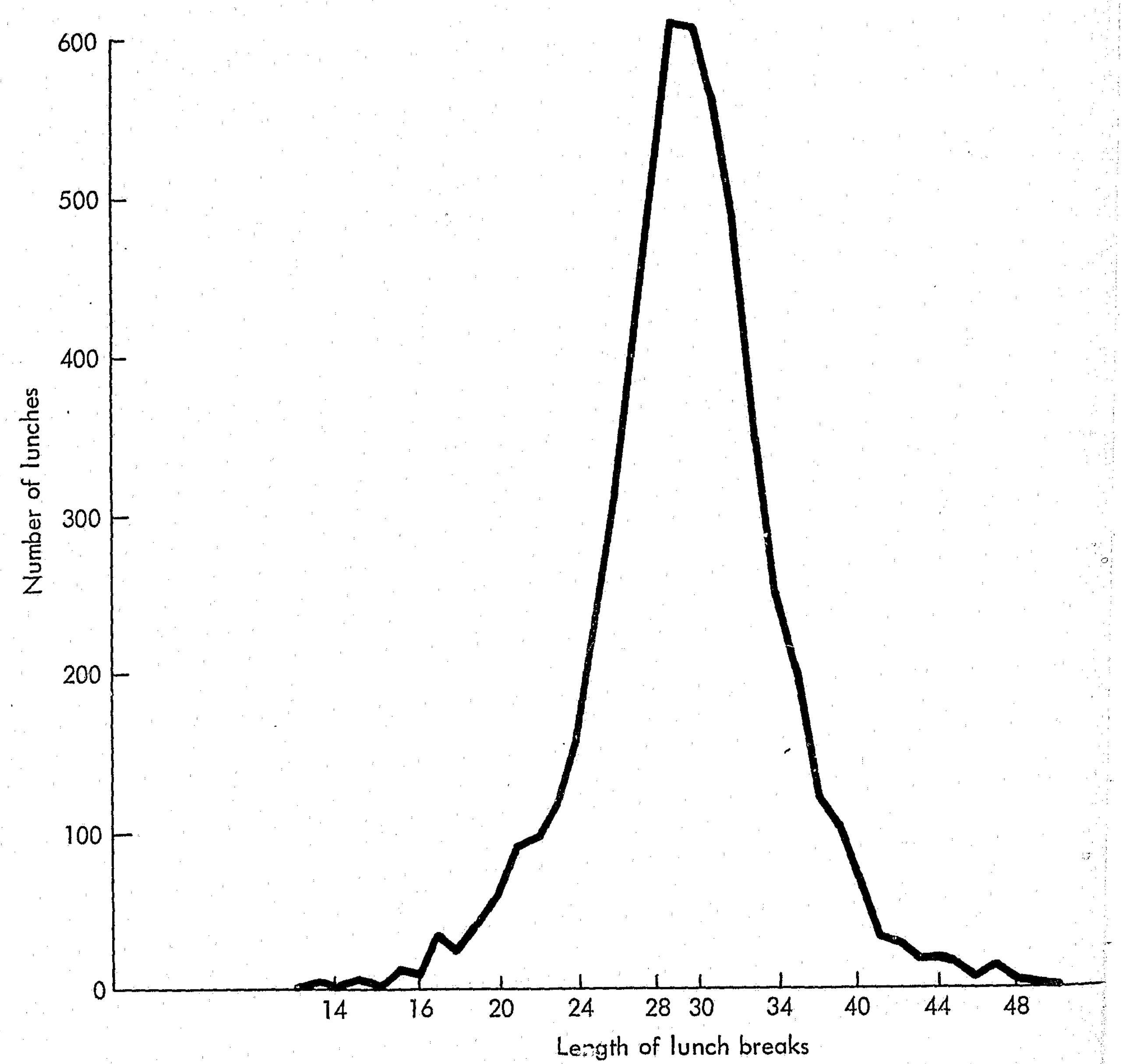


Figure 4-14 : Service Time Distribution for Lunch Breaks



The service time was a uniform number between 10 and 20 for personals and car service and for an empirical distribution for lunches (Figure 4-14)

VALIDATING THE MODEL

Ideally, the simulation model would be compared with actual response times and key characteristics of the real world for all eight districts. However response time data is available only for the 14th District. The model must therefore be validated against the 14th District data. A great obstacle to this is the fact tha there are too many unknown parameters, includin return speed, return route, response speed and start-u time.

When a beat car has been assigned outside his bea his position on returning to the beat is a function return speed and the route taken. The beat car supposed to return by the shortest route and can out preventive patrol inside his beat.

The patrol speed of a Task Force patrol unit is 9 mph. To determine the actual speed of Response For cars, patrol cars were asked to give their locati

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1 OF 3

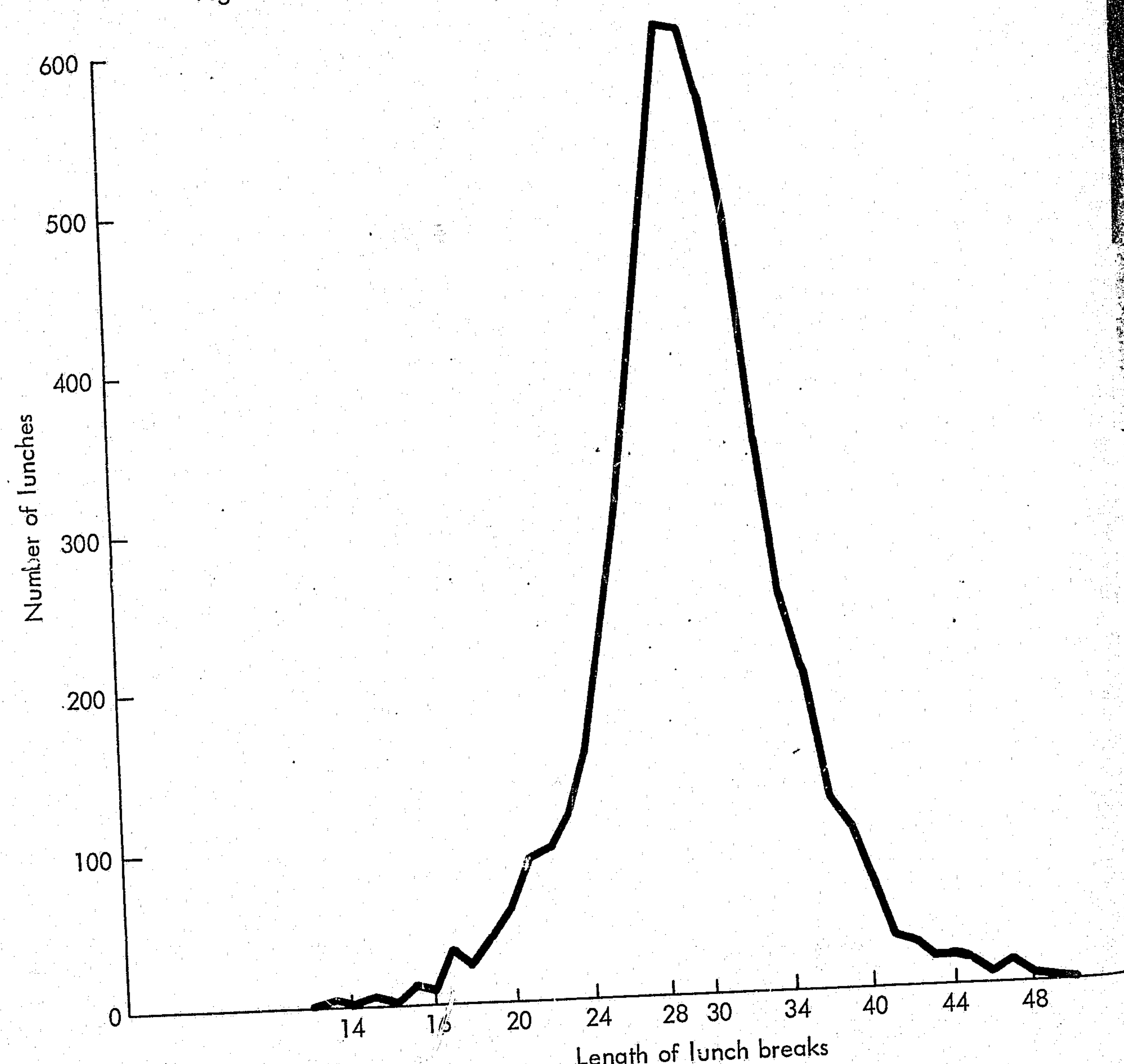

Figure 4-14 : Service Time Distribution for Lunch Breaks

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When a beat car has been assigned outside his beat his position on returning to the beat is a function of return speed and the route taken. The beat car is supposed to return by the shortest route and carry out preventive patrol inside his beat.

The patrol speed of a Task Force patrol unit is 9.2 mph. To determine the actual speed of Response Force cars, patrol cars were asked to give their location when assigned. Knowing the response time permitted the determination of the response speed. The average speed was 6.5 mph. This clearly indicates that a location was given which represented where the officer thought he ought to have been. In fact, both the response speed and the distance covered were higher. The conclusion must be that the shortest route back to the beat is not taken.

Neither the response speed nor the start-up time are known. The start-up time represents the time for receiving the assignment and reporting time of arrival to the dispatcher.

It is necessary to include this so that comparisons can be made with actual response times. The start-up time is set equal to 30 seconds. Fixing the return speed at 9.2 mph and determining the response speed which yields the best response distribution fit to real data yields 9.6 mph and a start-up time of one minute. (Chi-square is 6.00 for 15 degrees of freedom, significant at 2.5 per cent level.)

The dilemma is resolved by assuming that department policy is followed. After completing an assignment, the beat car will proceed at preventive patrol speed following the shortest route to his beat. The response speed is assumed to be 12 mph. Larson used this speed in his model, and experienced police officers felt that it was a good estimate.

The simulation model, therefore, is a picture of what the real world would be like under department policy and the assumed speeds. This is a valid problem formulation for this reason: The beat structure functions as a rough positioning tool and car locator mechanism. It is this system, working as it should, which is compared with a car locator system.

The model is validated against the following criteria:

1. Percent of calls for service answered by beat car or district car.
2. Minutes spent on administrative calls.
3. Number of car services, repairs, lunches, personals.

The average percent of calls answered by the beat car is approximately 23 percent, for district cars 63 percent. However these figures cover only August of 1969.

Demand has increased approximately 10 per cent, so the figures are closer to 20 per cent and 60 percent respectively. The simulation model yields 17 percent and 55 percent.

Figure 4-15 : Fourteenth District Response Times

Table 4–32

Test of Random Number Seeds To Initiate Simulation

	System variable		14th district	
	Test 1	Test 2	Test 1	Test 2
Mean response time (min.).......	8.50	7.37	6.44	6.13
Standard deviation...	10.32	7.59	5.81	4.99
Availability (percent).........	35	35	33	38

The simulation model generates the administrative downtime. Two weeks of data on administrative calls were collected in February, 1969, and downtime is related to behavioristic parameters. So it is safe to assume that these data will be representative. Approximately 69 minutes were spent on administrative calls per car/watch. The simulation model generates 64.3 minutes during eight hours of simulated time. The number of administrative events: 121 car services, 1 car repair, 127 lunches and 162 personals.

There are 132 cars in the simulated system, and almost all need service during an eight-hour tour. Just about every unit had lunch and registered one personal each. It is not necessary that all cars get two personals or lunch. Sometimes an officer skips lunch, and personals have to be permitted by the dispatcher. If availability is low, permission is not granted.

Different initialization periods were used: one-half hour, one hour, and 1.5 hours. One hour initialization period was sufficient to load the system. Real-world response times for the 14th District gave a mean of 7.68 minutes and a standard deviation of 5.65 minutes. (See Figure 4-15)

Statistics generated by the simulation model are random variates. An important question is the change that may be attributed to a different random number seed. Values are given for the key characteristics:

Table 4–33

Comparing Real World Performance and Simulated Performance Using Department Policy

	Real world	Simulation
Mean response time (min.).......	7.68	6.44
Standard deviation............	5.65	5.81
Mode.........................	4.00	4.00
Number of observations.........	454	84
Availability (percent)...........	35	35
Percent of calls answered:		
a. By beat car.............	20	17
b. By district car...........	60	55

Table 4–34

Comparing Dispatch Strategies With Normal Assignment Rules and Workload

	Mean (min.)*	Standard deviation	Mode (min.)	Availability (percent)
CM: System.....	8.50	10.3	3.0	35
14th district......	6.44	5.81	4.0	33
CL: System......	4.82	3.73	....	....

* The car locator reduces the mean response time substantially.

Mean and standard deviation of the response time distribution and the availability of cars for all eight districts. (See Table 4-32)

The results of comparing the actual system (eight districts) performance against that predicted by the simulation model following department policies is shown below (Table 4-33). The distributions are remarkably similar. Given the scope of the response distribution curve and relatively low number of observations, the mode is a better characteristic than the mean.

The alternatives to be investigated are center-of-mass (CM) and car locator (CL) strategies with respect to:

1. Present assignment rules with (a) normal workload and (b) reduced workload.
2. Interdistrict dispatching with (a) normal workload and (b) reduced workload.

Case 1-a (Present assignment rules, normal workload): The statistics for the present system following department policy under a center-of-mass dispatching strategy is compared with a car locator system. The only difference between the two alternatives evaluated is the knowledge of the exact location of the car by use of a car locator. The important characteristics are the average response time, its standard deviation and availability. Availability is related to the ability to carry out trapping and search maneuvers. (See Table 4-34) The results are shown graphically in Figures 4-16 and 4-17.

Table 4–35

Comparing 2 Dispatching Strategies With Reduced Workload

	Mean (min.)	Standard deviation	Mode (min.)	Availability (percent)
CM: System.....	5.92	6.98	3.0	45
14th district......	4.68	2.24	4.0	48
CL: System......	3.77	2.87	2.0	....

Figure 4-16 : Response Times for Dispatching Strategies

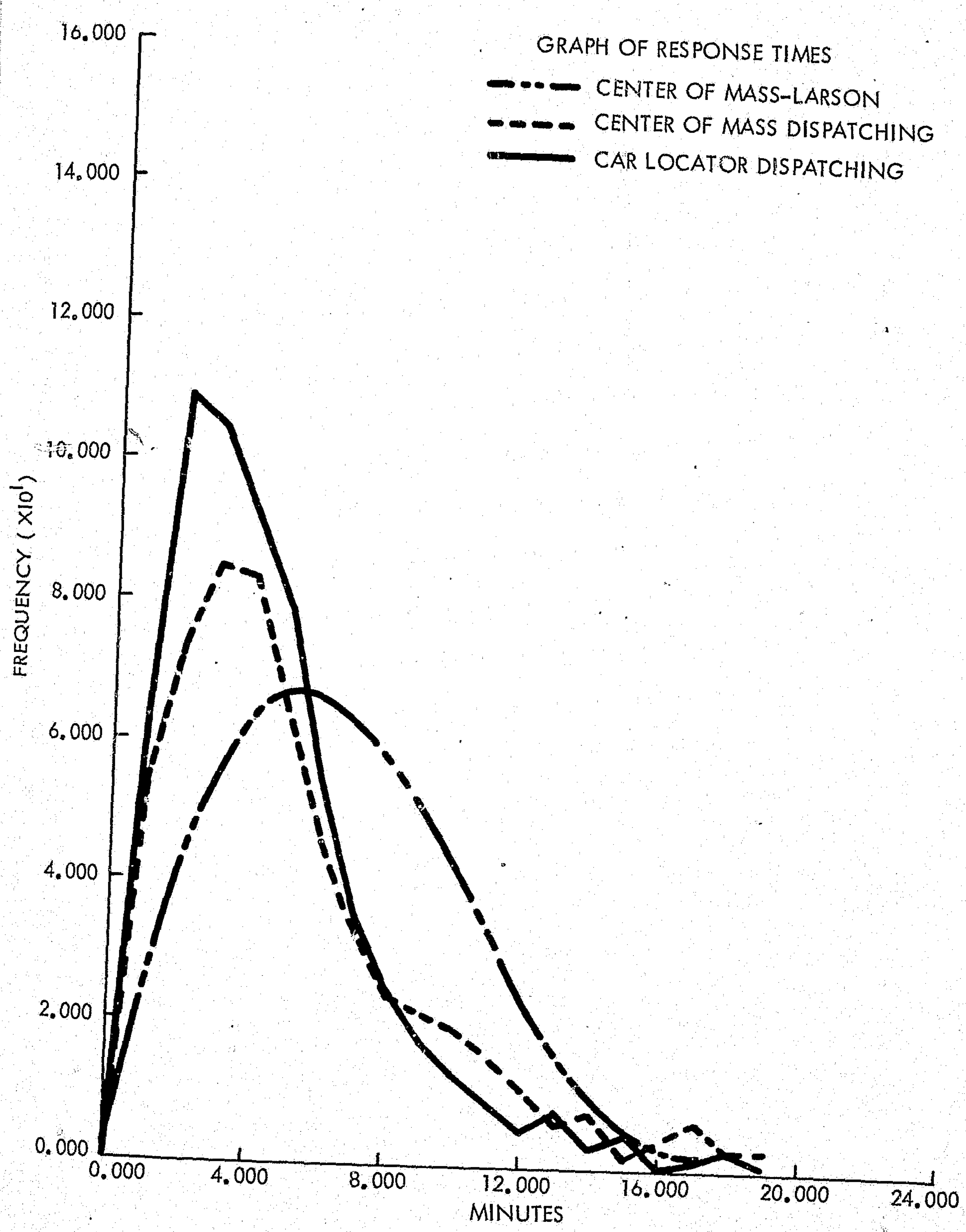


Figure 4-17 : Fourteenth District Response Times

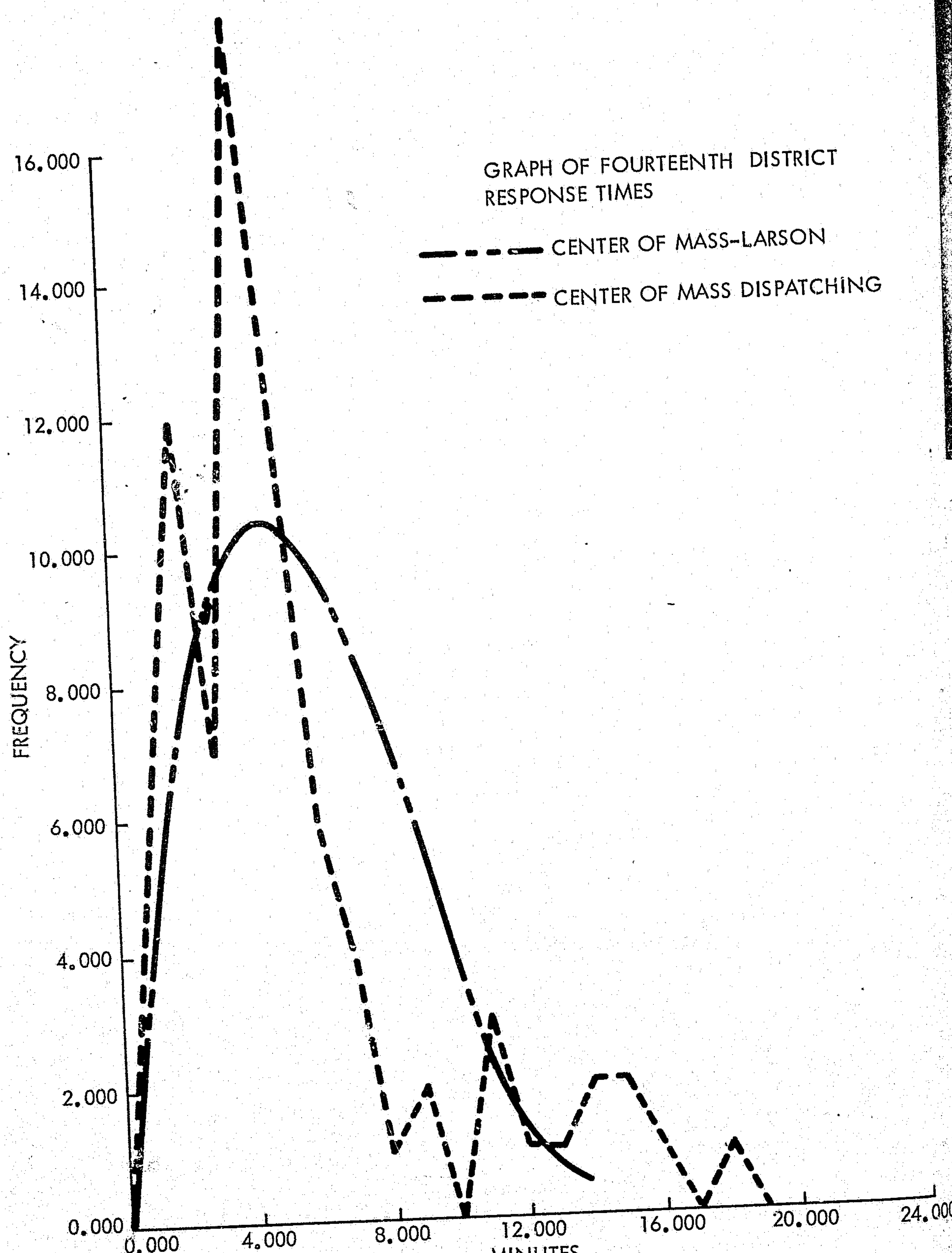


Table 4–36

Comparing 2 Dispatching Strategies With Interdistrict Dispatching

	Mean (min.)	Standard deviation	Mode (min.)	Availability (percent)
CM: System.....	5.89	7.47	3.0	39
14th district.....	6.16	9.97	5.0	39
CL: System......	4.37	3.90	3.0	....

Case 1-b (Present assignment rules, reduced workload): One effective way of increasing availability and decreasing response times is to decrease the number of calls to which one responds. This policy has been instituted in St. Louis and Detroit. Incoming calls are evaluated by an experienced police officer who determines if police service really is needed. A 30 percent reduction of miscellaneous-other calls is assumed. Probably this would represent an upper limit of call screening as indicated by the data. The outcome is a reduction in response time that is greater than that shown by using a car locator in the previous case. (See Table 4-35)

Figures 4-18 and 4-19 show this dramatic reduction in call response time.

Case 2-a (Interdistrict dispatching, normal workload): Interdistrict dispatching means that the nearest car is dispatched, even if the car belongs to a district different from the location of the call for service. Current department policy, for reasons of administrative efficiency, does not permit this alternative. Comparing the results of this strategy (Table 4-36) with the earlier case, makes it clear that reduced workload has a larger effect (because the availability factor is much greater) than simply allowing interdistrict dispatching. (See also Figures 4-20 and 4-21.)

Case 2-b (Interdistrict dispatch, reduced workload): The possibility certainly exists of combining the two alternatives. This was done, and it is clear that still more improvement in response time occurred. However availability did not change much from Case 1-b. (See Table 4-37 and Fig. 4-22)

Table 4–37

Comparing Dispatching Strategies With Interdistrict Dispatching, Reduced Workload

	Mean (min.)	Standard deviation	Mode (min.)	Availability (percent)
CM: System.....	4.53	4.37	2.0	48
14th district.....	3.86	1.85	4.0	47
CL: System......	3.66	3.10	2.0	....

Table 4–38

Comparing Dispatching Strategies With Interdistrict Dispatching Under Reduced Workload With Car Locator Assignment

	Mean (min.)	Standard deviation	Mode (min.)	Availability (percent)
CM: System.....	4.43	4.36	2.0	....
14th district......	3.69	1.97	2.0	50
CL: System......	3.69	2.96	2.0	48

The fact that cars were actually dispatched using the center-of-mass strategy introduced the possibility of a hidden uncertainty. What bias is introduced into the car locator strategy results by not actually dispatching according to a car locator strategy? To determine this, cars were dispatched using the car locator assignment criteria for the interdistrict, reduced workload (Case 2-b). It is evident that the error introduced by evaluating a car locator system when cars are actually dispatched according to the center-of-mass strategy is negligible. (See Table 4-38)

Combined Strategies Favored

It is clear that the car locator system does not improve system efficiency greatly by itself. At most, two minutes are saved. When interdistrict dispatching or screening are allowed, the average value falls by approximately 2.5 minutes. When both policies are used, the saving is 4 minutes.

By making an administrative change, interdistrict dispatching will increase the average availability from 35 percent to 39 percent. This saving is realized solely from less cross travel since everything else remains the same for the two alternatives.

The most spectacular result is achieved by combining the two major alternatives. The average response time and standard deviation drops in half, and the modal value drops by a full minute. At the same time, the availability factor increases from 29 percent to 48 percent. The car locator offers a saving of an additional minute.

The conclusion must be that the greatest savings lie in policy changes rather than hardware. However the car locator system might be worthwhile, given the other changes. For the car locator, in addition, offers great opportunities for supervision. This probably would result in shorter service times, more time on beat patrol and release of supervisory personnel for other duties.

Figure 4-18 : Response Times with Reduced Workload

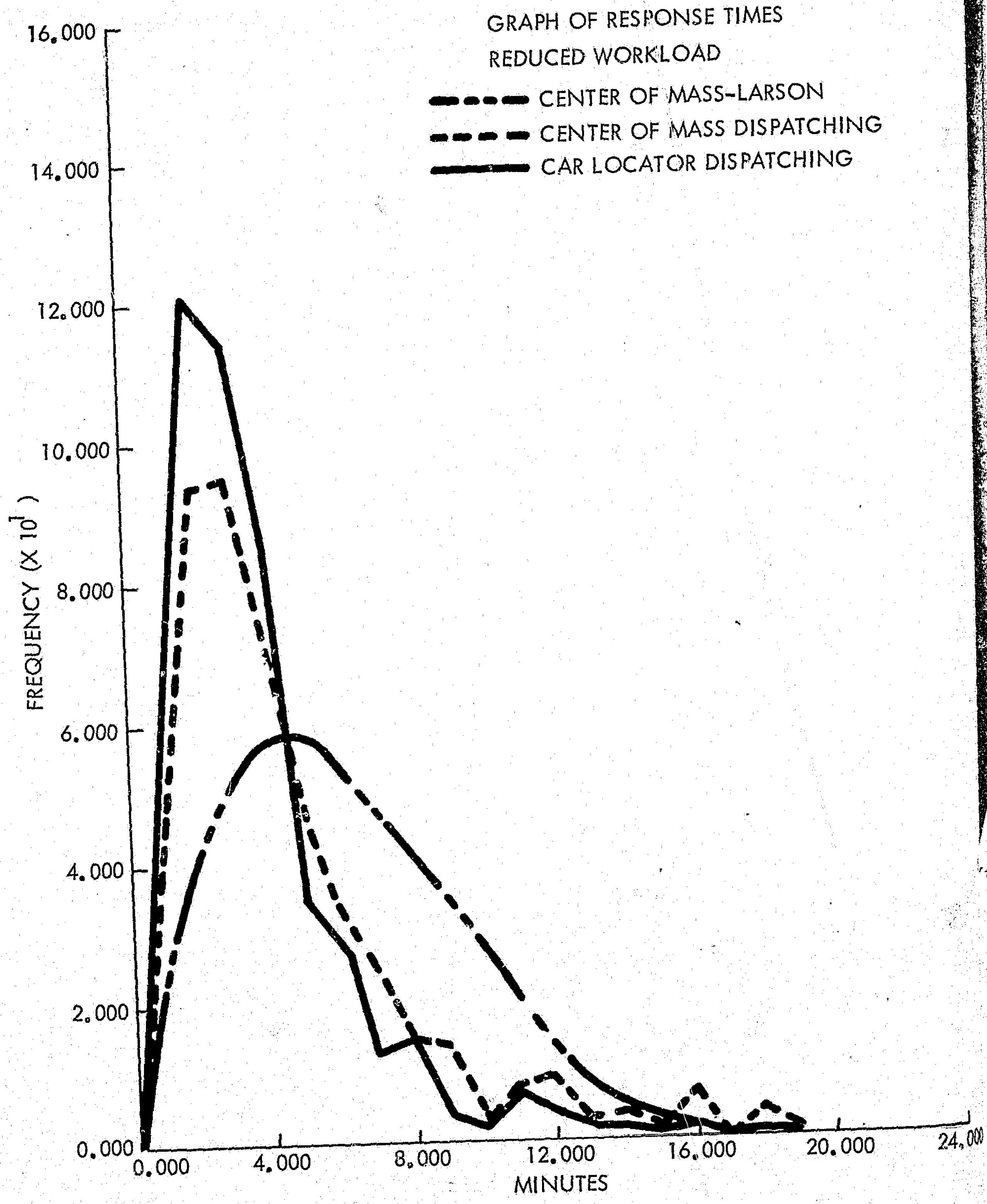


Figure 4-19: Fourteenth District response times with reduced workload.

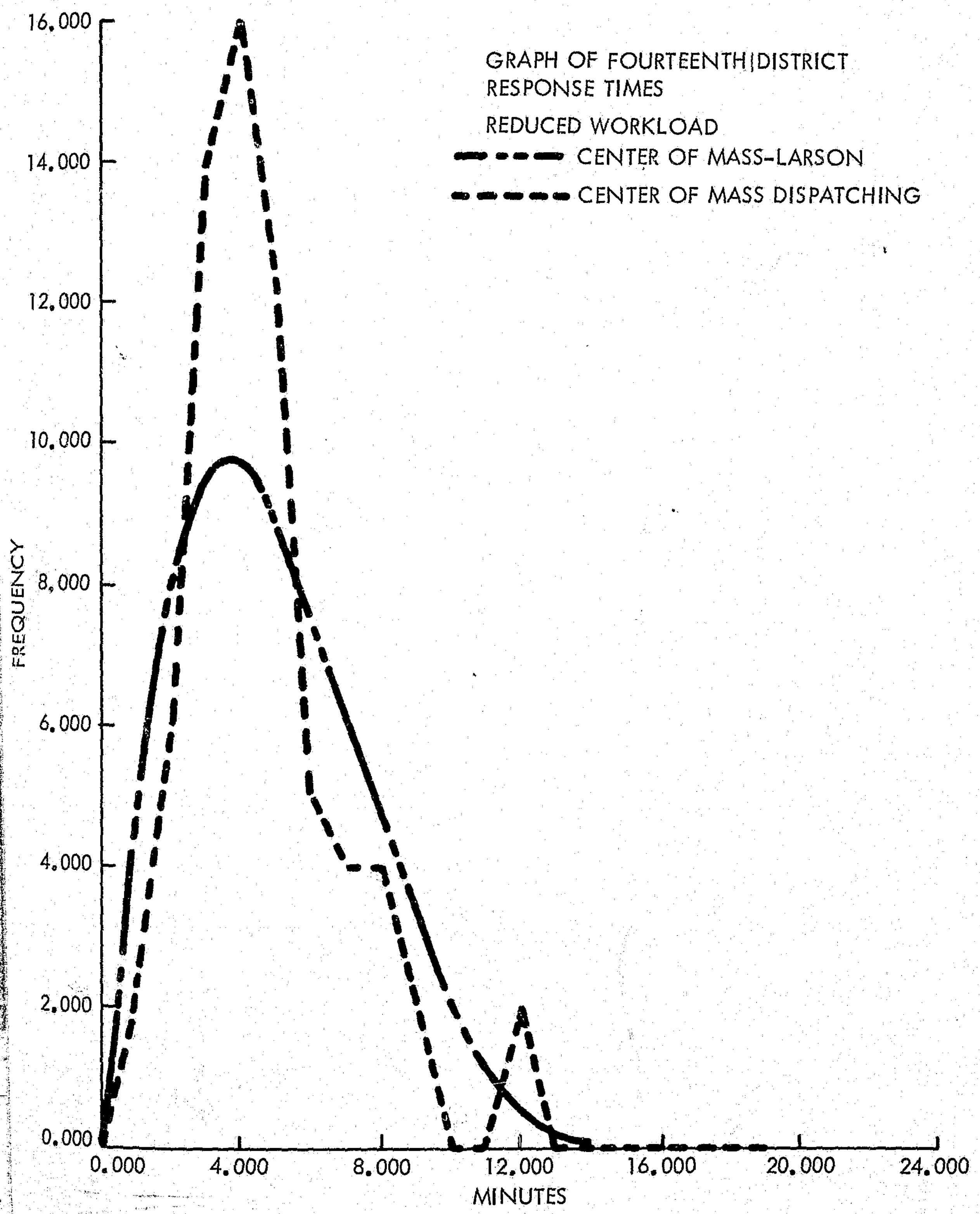


Figure 4-20 : Response Times for Interdistrict Dispatching with Normal Workload

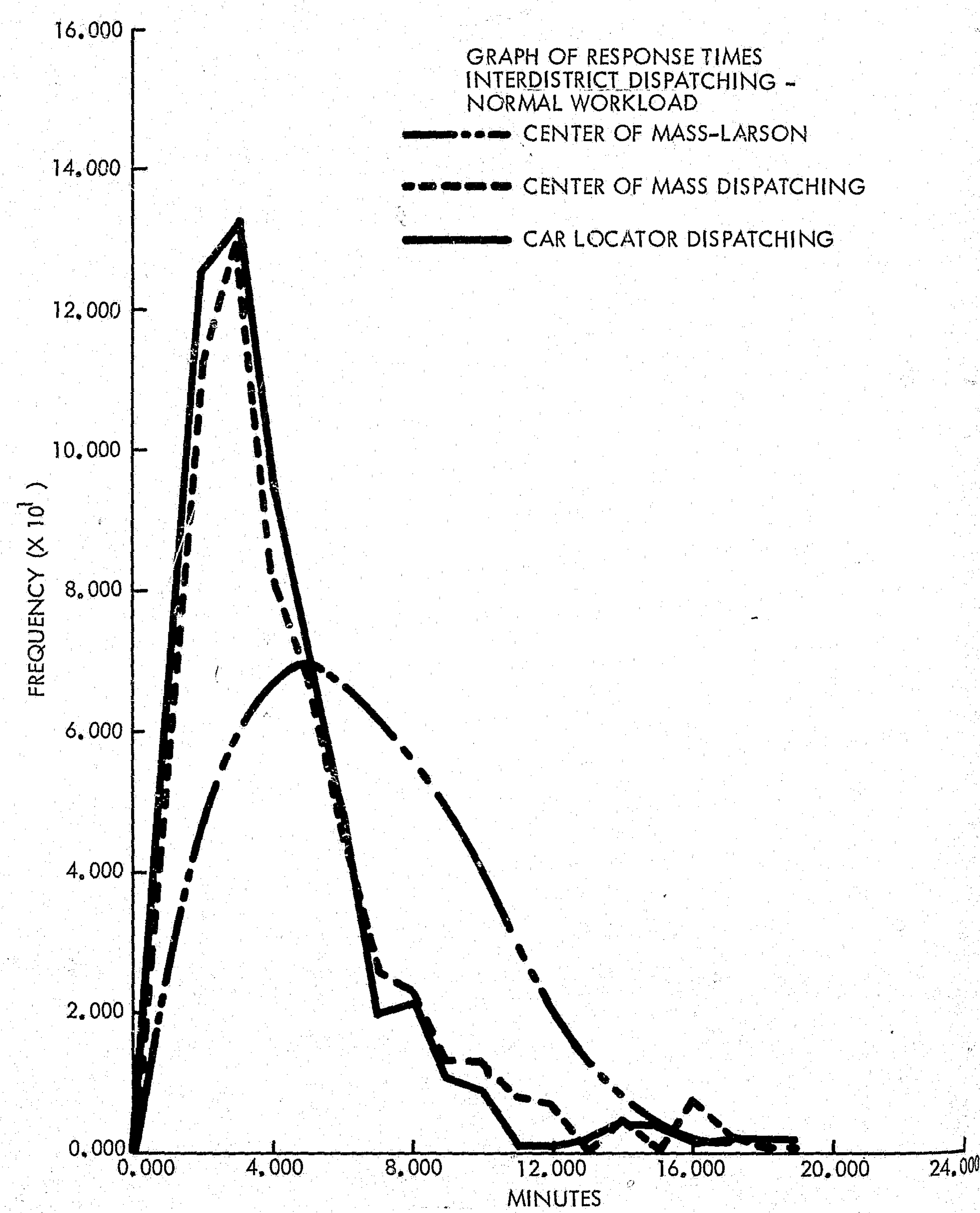


Figure 4-21 : Fourteenth District Response Times for Interdistrict Dispatching, Normal Workload

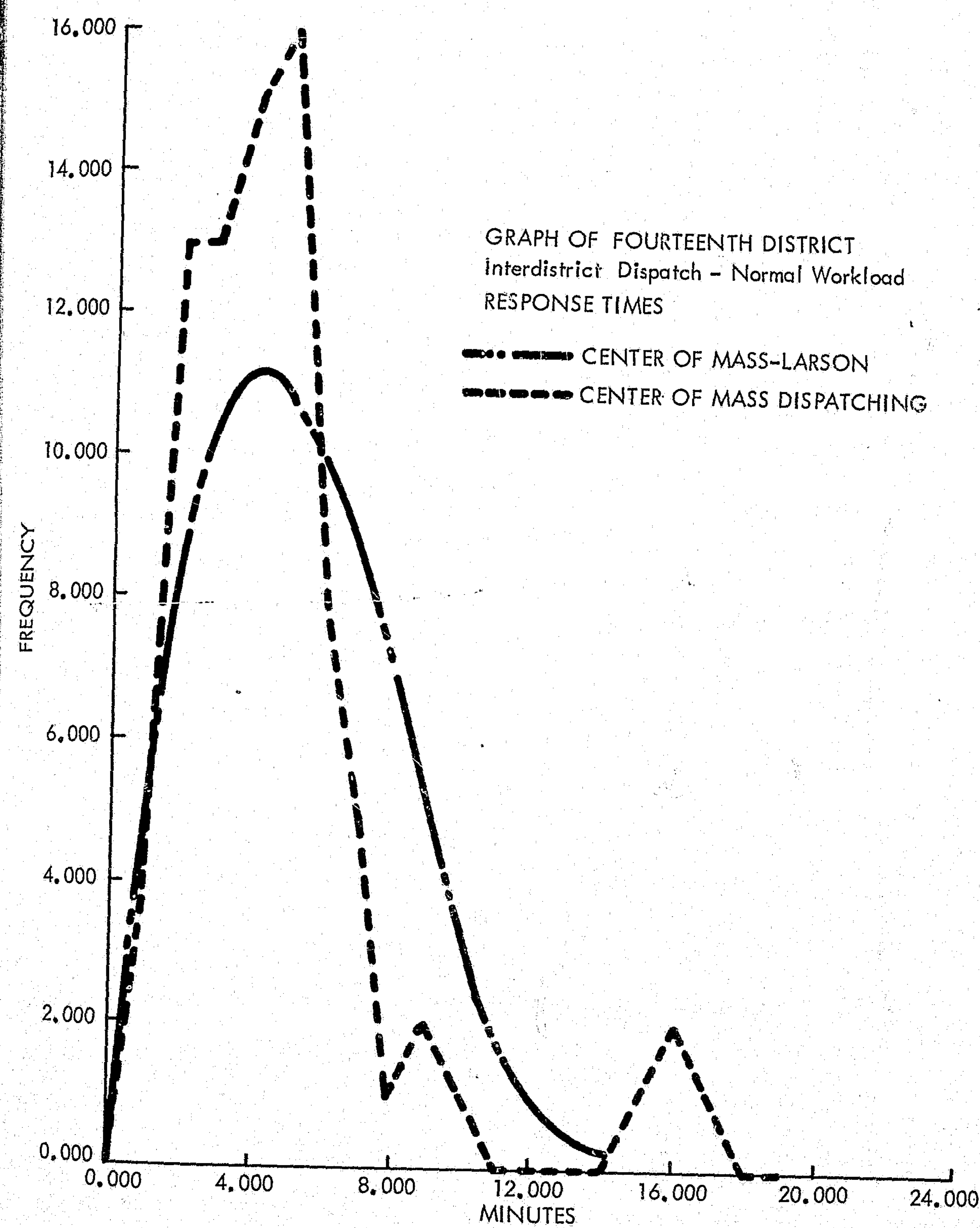
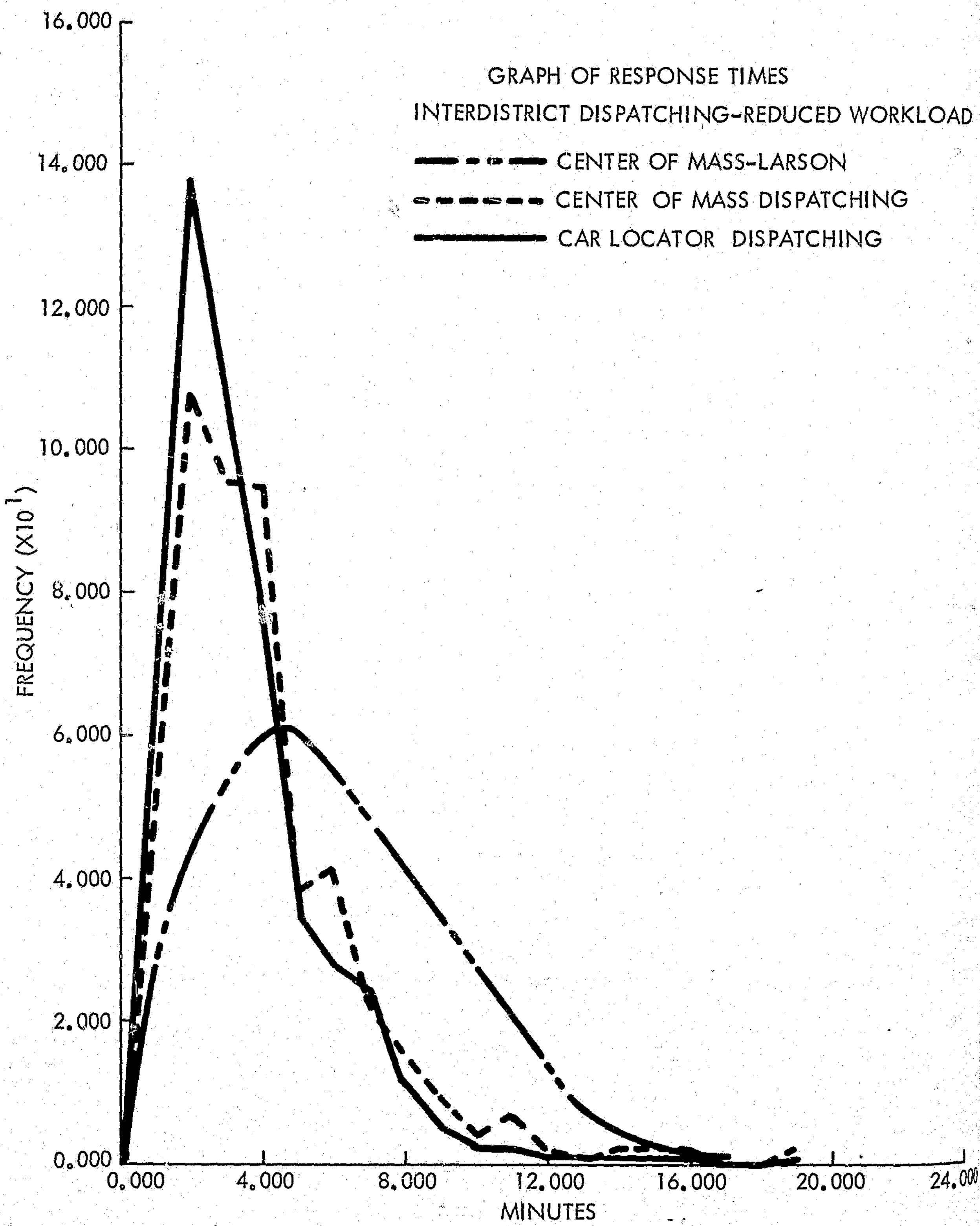


Figure 4-22 : Response Times for Interdistrict Dispatching with Reduced Workload



'Blue Fence'—Coordinated Trapping

The probability of arrest is strongly related to the elapsed time between a criminal event and the arrival of police on the scene (time-late). The probability of arrest dropped significantly in a study made by the Los Angeles area when time-late increased from 4 to 6 minutes. Everyday traffic congestion alone increases the difficulty of reducing time-late to as little as 4 minutes. Certain barrier and search tactics were tested in Chicago under the code names Operation Blue Fence and Operation Blue Rake. The tests were revealing in regard to the number of units required in various situations.

The number of units required to contain an offender in an area and institute methodical search can be estimated by use of analytical relationships. Quantities can be verified by actual test. A knowledge of absolute force requirements is a prerequisite to cost-benefit analyses and the allocation of resources among competing alternatives.

The Chicago Police Department employs cooperative tactics, based on voluntary response, for "Lookout" or "Flash" messages. This involves the patrol of quadrants to seal the scene of a crime rather than having all units proceed to the scene by the most expeditious route.

This tactic has the advantage of minimizing radio traffic, thus enabling a zone dispatcher to handle other calls for service. A disadvantage is that the assigned beat car and his supervisor do not know the extent to which containment has been effected by the dispatcher.

In 1960, the St. Louis Police Department experimented with coordinated tactics known as the "St. Louis 100 Plan." This employed hexagonal templates based on elapsed time to position blocking units. Experiments showed better than 60 percent success in apprehending individuals attempting to elude the police. To date, the Chicago Police Department has made little use of coordinated tactics.

The methodology of such coordinated tactics deals with an "area of uncertainty." If the criminal is not constrained to follow streets, the area of uncertainty is the area of a circle whose origin is the scene of the criminal event and whose radius is given by the product of the *velocity* with which the criminal can flee and the time-late. In this somewhat abstract case, the area of uncertainty (A) is given by

$$A=\pi(T_L V_c)^2$$

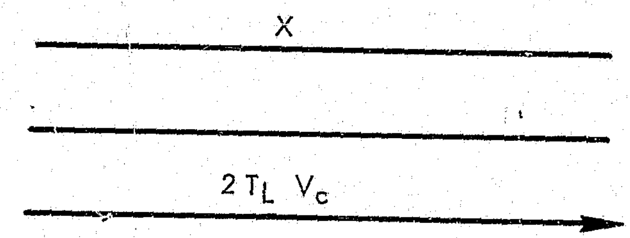
where

T_L=Time Late

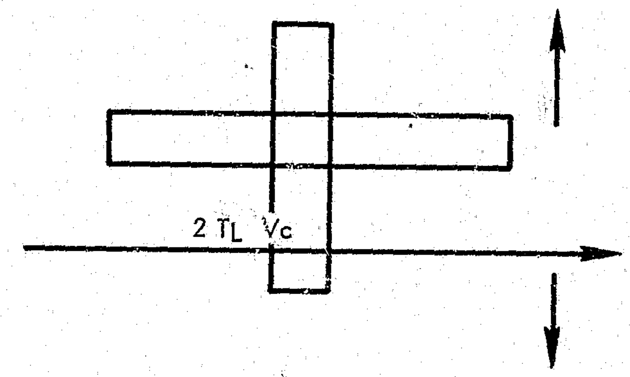
V_c=velocity of the criminal.

This case might approximate the situation where a criminal having familiarity with a region can flee in almost any direction by using gangways, basements and rooftops as well as streets.

When the fugitive is constrained to streets and alleys, the geometry of the area of uncertainty becomes more complex. Along a single road, the area of uncertainty is a rectangle having as its long axis the distance equal to twice the product of time-late and the escape velocity.



At or near an intersection, the geometry and distances are depicted below,



If criminal flight is not constrained to streets and alleys, blocking force requirements will be determined by the perimeter of a circle, or:

$$C-\pi d=2\pi T_L V_c$$

The perimeter is the important parameter in this case because escape can be made at any point of the perimeter. Blocking units must be positioned uniformly around the circle.

A case of practical importance occurs when flight is constrained to streets and alleys and the blocking positions are the intersections of streets and alleys with the perimeter of the area of uncertainty. Geometrical problems can be reduced further if information exists about the quadrant and dominant direction of flight. Naturally a knowledge of the entire area involved is of great importance in all "hot search" tactics.

Search Theory Considerations

The outcome of a search of an area for suspects is described in terms of the probability of arrest. This probability is the result of the joint occurrence that the subject is detected by a searching unit, that the subject is identified as the individual being sought and that a physical arrest is made. In order to make use of the probalistic concepts in estimating how many searching units are needed to yield acceptable probabilities of success, it is necessary to state the probabilistic events in terms of quantities that are physically measurable.

Let P be the probability of successful search, identification and arrest of a suspect; then:

Pd = Conditional probability of detection given search in a suspect probability area—SPA.

Pi = Conditional probability that the suspect will be identified if detected.

Pa = Conditional probability of physical arrest given identification.

These conditional probabilities can be computed as follows:

(a) Pa—It is assumed that the conditional probability of physical arrest given identification is nearly unity. Some possibility exists that the subject will break free or that one or more subjects will escape in a multiple arrest situation.

(b) Pd—This quantity is related to the detection law that governs a policeman detecting an individual in his immediate vicinity. In general, the eye is the detection device although on occasion aids such as dogs or night vision devices may be used. The most common situation, unaided visual detection, may be described to a first approximation as following a definite range law.

The definite range law states that all targets existing within Range X of the detecting unit will be detected; none beyond Range X will be detected.

Studies of the process of visual detection have produced empirical methods for estimating detection range in terms of contrast between target and background, relative elevation of searcher and target and the extent to which smoke and haze are present. For street application, it is important to know contrast and whether the search is a daytime search or at night.

Each searcher will be able to search area of $2xrt+\pi x^2$ where X is the effective detection range

T is the duration of search

r is the rate of search

A single search unit, searching for time T will search a fraction of the total SPA, A, given by

$$\frac{2xrt+\pi x^2}{A}=\begin{cases}\text{Pd}(2xrt+\pi x^2)<A\\ 1\,(2xrT+\pi x^2)\geq A\end{cases}$$

Assuming the definite range law, the above is also the probability of detection for a suspect who may be located anywhere in the area. When n units are searching, and under the assumption that there is no appreciable overlap in their search, the Pd is estimated by

$$\frac{n(2xrt+\pi x^2)}{A}=\begin{matrix}\text{Pd when } n(2xrt+\pi x^2<A\\ 1 \text{ when } n(2xrt+\pi x^2>A\end{matrix}$$

The same relationships hold if the problem is considered from the standpoint of the criminal and if he uses his detection range of the police to avoid contact. If X', the criminal detection range for the police, is greater than X, the police detection range for the criminal, the criminal can avoid detection unless the searching units are coordinated so that it is impossible for the criminal to stay outside any of the police detection circles.

It should also be pointed out that criminal attempts to use radical evasive actions may serve to call attention to his presence; this increases effectively the value of the police detection range X.

$2.4(c)P_i$

The probability of identification of a suspect depends critically on the nature of the information. It is particularly important that distinguishing information be obtained. A person in bizarre dress or employing a distinctive automobile for escape may be identified simultaneously upon entering the detection circle. In other situations, identification may be possible only by searching the individual. This act requires the searching unit to approach the suspect and expend some time in the search. Time expended in approaching and interrogating suspects is time lost from the basic search, so the formulae in the preceding section must be corrected to account for delays due to "false" targets.

Let (t_f) be the time expended in search of (m) nonproductive street stops. The effective coverage then becomes

$$\frac{n2xr(t-mt_f)+\pi x^2}{A}=P_d$$

if all searching units are similarly deployed. This correction is valid if (mt_f) is smaller than (t).

When the total of (mt_f) approaches (t), the searching unit becomes immobilized, and the patroling officers can investigate only a fraction of the targets detected.

Field Measurement of x

The range of detection, (x), will vary with the local environment, presence of other people, location and number of obstructions, etc. Clearly, no single number describes (x). At the same time, some method of estimating searching force requirements is desired. Quantitative estimation of force requirements depends upon knowledge of physically measurable quantities.

Consider the following experiment. By interview or by actual field test, obtain estimates of the distance at which a suspect was initially detected. Use as large a sample size as possible. Divide the sample into those searches occurring during daytime and those at night. Subdivide the sample further to account for major factors that would affect detection capabilities, such as night-street-crowded vs night-street-empty.

For each environmental category chosen, form a frequency distribution of the initial detection occurring in 0–10 ft., 10–20 ft. and so on, out to the maximum reported detection range. The result could resemble the following histogram (Figure 4-23):

Plot the cumulative distribution frequency of detection by range (Xi) where (i) refers to the range interval. (See Figure 4-24.)

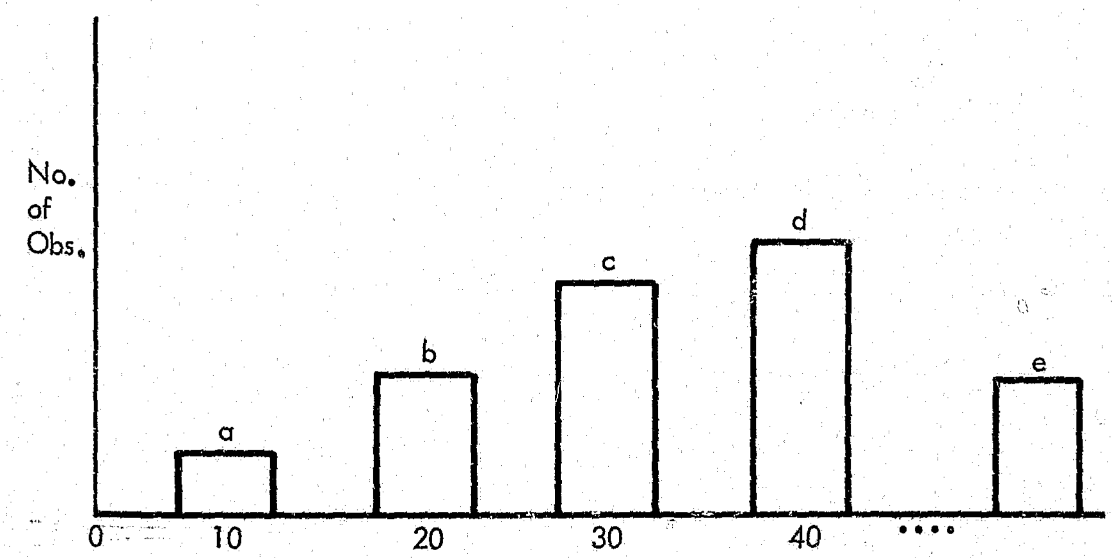
It is expected that the cumulative probability of detection curve will approximate a rectangle if the definite range law applies and if the conditions that existed when the sample points were chosen were reasonably common to all. An operational approximation of the average detection range for the specified conditions is the abscissa corresponding to the ordinate of Probability of Detection of 0.5. Determination of the appropriate operational detection range under the different conditions that can be expected is the first step in designing search tactics and computing forces required to execute the tactics.

The blocking geometry is determined by the speed at which the criminal flees the scene of the criminal event, V_e, and the time-late T_L. In this context, time-late has a different composition than is commonly encountered in police tactical doctrine. Normally, time-late is measured from the time the criminal event (t) occurs until the first investigating officer arrives on the scene. In this present case, time-late is measured from the time of commission of the crime until most of the blocking force can be positioned. Since this positioning of the blocking force will involve summoning of police resources from points away from the beat of occurrence, it is to be anticipated that this elapsed time will be greater than is experienced in the immediate response to the victim.

Since both the perimeter of the area of uncertainty and the enclosed area that has to be searched both depend on the magnitude of time-late, as read in this context, it is desirable to develop operational procedures that minimize the time response for positioning the blocking force.

Time-late will have to be established on the basis of experience. Flight velocity can be estimated from knowledge of traffic conditions in various parts of the

Figure 4-23 : Range of Detection, x, in ft.



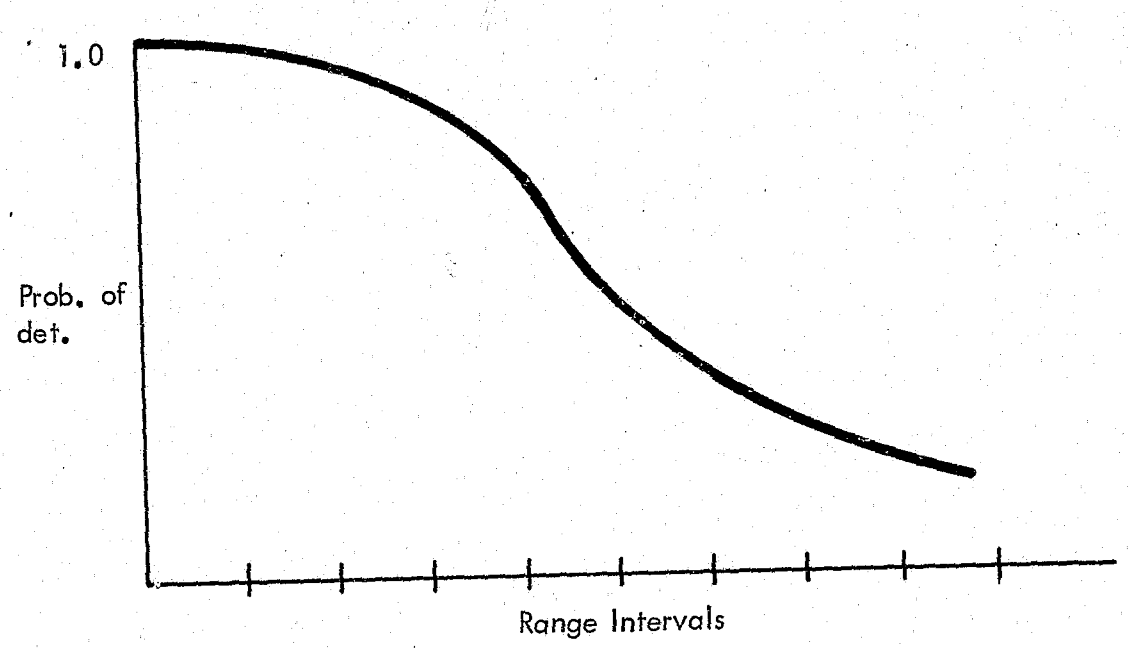


Figure 4-24 : The Cumulative Detection Function

city and at various times of the day. When flight is on foot, the sustained rate would be about three mph.

When information about the occurrence of a criminal event is delayed (The victim does not call police immediately.), this delay must be added to the time required to position blocking forces. Delay increased the perimeter that must be covered by the blocking force as well as the area to be subjected to hot search.

In practice, it is considered that a family of templates corresponding to different values of time-late could be provided the dispatcher to assist in positioning of the blocking force.

In Operation Blue Fence, the force requirements to set up blocking positions for the quarter-ellipse were depicted on a table. Entries on the table were determined by placing the ellipses that determined the SPA on a map and counting the numbers of intersections of streets with the edge of the ellipse. The region of the Second District chosen was typical of the residential areas lying east of State Street. Force requirements will vary in various parts of the city, depending on the size of blocks and the presence of diagonal avenues, such as Milwaukee Avenue.

Intersections of alleys on the edge of the ellipse also represent sites where blocking units might be stationed. However, it is assumed that adequate coverage of streets and flanking alleys can be obtained from one two-man unit. The table used in Blue Fence is shown in Table 4-39.

Table 4–39

Unit Requirements for Blue Fence on Function of Speed of Escape and Time-Late for Quarter-Ellipse

Miles per hour	Minutes	Units
3	15	3
5	5	4
3	15	7
10	5	7
15	15	9
5	15	9
3	30	11
10	15	16
5	30	15
15	15	24

Hot Search: 'Blue Rake'

Once the blocking force is positioned at the perimeter of the SPA (Subject Probability Area), the next step is to commence methodical search of the SPA.

Tactics for carrying out the search will vary with the kind of environment. A form of general area coverage, for example, would be appropriate for open areas such as parks or vacant land. In the built-up areas that consist of single-family detached homes, search tactics would have to include yards, alleys and outbuildings, such as garages. Searching units should be pairs of men in order to provide mutual support and to prevent the suspect from eluding search by moving through side yards not covered by police.

One important aspect of search is that the actions of the suspect are constrained so as not to arouse suspicion. Thus he only succeeds in drawing attention to himself by running or by driving fast.

Dense neighborhoods consisting of row houses or connected store fronts present an easier search problem than does the detached single-family dwelling neighborhood. There are no interstitial spaces between structures. However, if the suspects are able to invade premises or move through connecting basements or over roofs, the region becomes very difficult to search, and it has all the properties of a sanctuary.

In the sanctuary situation, police effort is concentrated on making contact with residents in the hope of obtaining information on the identity or whereabouts of the subject. Willingness of inhabitants of a sanctuary-like area to assist the police with information is a direct measure of the effectiveness of the various public relations and community support programs. It is anticipated that the on-scene commander with knowledge of a particular area would know to what extent search should be attempted in a sanctuary area.

A method by which the operational probability of detection can be calculated from observed data will be discussed in connection with development of preventive patroling tactics.

The necessity to stop and interrogate individuals detected during a search slows the effective rate of coverage in an area. In crowded areas, an even more significant effect is that many individuals may be detected but escape inspection or questioning because the searching units are busy with other subjects. In many cases, it may not be feasible to detain passers-by until they can be examined.

Continuing with the effort to obtain quantitative guidelines for estimating forces required for a given assignment, it may be worthwhile to review the information available in an area or about the interrogation process that has been or can be measured. One method of estimating searching unit requirements is to regard the process as a queuing problem similar to the one used in designing the response force. Rationale for the approach is this:

The act of interrogation or stop-and-frisk may be thought of as a service performed by the searching unit. It is possible to obtain the service time distribution by observing street stops. It is also possible to discover in various areas and at various times of the day the number of people enroute as a function of time. Thus it is possible to obtain arrival distributions.

If the searching unit is considered as a single server, it is possible to calculate the delay that the citizens on the street will experience if they are forced to await interrogation. If it is infeasible to have people wait to be interrogated, the probability that a person on the street will have to join a queue and hence be lost can be estimated. In this latter case, the efficiency of the search is estimated by the probability that the encounter cannot end in interrogation.

Force requirements to carry out any predetermined level of search can be calculated by considering each additional search unit as a parallel channel. The effect on efficiency of search of various policies concerning the length of the queue that will be allowed to develop can be estimated from the queuing approach.

If the observed statistics concerning rate of encounters and the service time distribution fit the case of Poisson arrival and negative exponential service, the standard formulae can be used to estimate searching force requirements. Computer simulation of the multi-server case is readily carried out for cases in which the arrival and service statistics cannot be approximated by simple analytical expressions.

Time is of the essence in positioning the blocking units. Efforts should be made to erect the barrier simultaneously with the dispatch of the beat car to respond to the victim. Undoubtedly some procedural changes will be required in the Communications Center. The question is whether the disadvantages of tying up a Zone Operator for a few minutes are offset by the increase in the probability of apprehension of the criminal. Under what conditions is it effective to institute blocking procedures?

The discussion in the previous section showed some of the geometrical considerations. Under some situations, it is conceivable that not only the direction of flight but also the quadrant may be surmised from knowledge of the areas. For example, it has been noted that high incidence of robbery occurs in areas contiguous to public housing projects. It has been suggested that the housing project acts as a sanctuary for the criminals. The orientations of blocking patterns should take this into account.

Although several search alternatives may be set up for experimentation or implementation, only two (Close Control and Broadcast Control) are discussed here. Prior to experimentation or implementation, the coordinated blocking tactics would be explained to all Field Forces which might participate. To minimize interference with this assignment, 10–12 units might be alerted to expect blocking force duty at the beginning of the watch. Time could be saved by calling an alerted unit, giving him the blocking position assignment and having him receipt for the assignment after he is in position. There is risk that the unit will miss the call and the blocking will not be completed.

Close Control (Alternative 1) requires these procedures from the Zone Operator at the Communications Center:

1. Zone operator obtains time, place, brief description, direction, and method of flight for use in flash message.
2. Zone operator assigns beat car to respond to victim, obtain amplifying information, and commence hot search in immediate vicinity of crime. Do this on Zone and Simulcast.
3. Zone operator selects appropriate blocking template. Selection based *a priori* estimate of how long it will take to position the blocking force. This determination will be based on experience and general knowledge of travel time in affected area.
4. Zone operator consults line-up of motorized units from District Tactical Units, Task Force, Detective, Vice, Umbrella beats and Squadrols available in the zone.

After the blocking pattern has been established, the responding beat car issues any amplifying information, and the on-scene commander initiates hot search by using the responding unit, by contracting the blocking perimeter and by using other mobile units that may be available in the area.

Broadcast Control (Alternative 2) takes into consideration this situation: At time of peak loading it may be infeasible to tie up the Zone Operator to position blocking forces, or insufficient blocking units are available. Then it may be useful to modify the *Close Control* process. In the Broadcast Control operation, the zone or city-wide operator gives the position at which blocking units are desired. He uses an appropriate template. The blocking positions are filled by casual units as they report. As time passes, and the area of uncertainty grows, the dispatcher should select a larger template and give the new dimensions of the area of uncertainty. It would help for mobile units to be equipped with maps and grease pencils to assist in maintaining a working plot of the developing tactical situation.

If any new information is received about whereabouts of suspects or direction of flight, such information can be used to update, contact or shift the SPA. Provided there are adequate blocking and searching units, and provided that they can be repositioned, *information update* is equivalent to reducing time-late. In this manner, update will lead to concentrating the search in "profitable" areas.

Since it is likely that those interested in systems applications of these techniques, the Operations Task Force suggests standardizing nomenclature along these lines:

Operation Blue Fence (Containment exercise).
Operation Blue Rake (Search of the SPA).
SPA (Suspect Probability Area).
Sanctuary (Area virtually impossible to search).

A great variety of ellipses are available in standard templates. However it is more likely that experimenters will want to develop a standard template to fit their local map scales and assumptions or to construct templates on demand. Directions for construction of an ellipse are included here to avoid a niggling search through elementary texts.

1. Determine scale of base map (inches per 1000 ft.)
2. Locate foci on major X axis of ellipse.
3. Cut string doubled at length.
4. Attach ends at foci of ellipse.
5. Trace ellipse with grease pencil in bight of string stretched tight.
6. Cut out transparent acetate template using constructed ellipse as a pattern.

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CHAPTER 5

THE PREVENTIVE PATROL FUNCTION*

In structuring the problem of allocating patrol resources, attention has been focused on three principal functions: Response, Preventive Patrol and the Investigative or follow-up function. Methods for allocating resources to carry out the response func- were discussed in the previous chapter. The resultant allocation can release manpower resources for specific assignment to the Preventive Patrol function. These resources, termed the Preventive Force to distinguish their employment conceptually from other potential uses of resources, can be allocated so as to maximize potential results.

For purposes of analysis, the assumption is made that these resources would be deployed against the serious crimes, felonies that are most susceptible to detection and prevention by the police. These crimes are robbery, burglary, and auto theft.

This chapter is particularly important in that it represents an attempt to develop analytically and quantitatively based methods for the use of resources that are freed for preventive patrol. Much remains to be done in developing the theory of preventive patrol. The ideas and techniques presented result from specific needs that were perceived in conducting studies of bus robbery, street robbery, and task force activities. The methods reported in this chapter are increasingly significant when evaluating major results of the administrative experiments carried out in the 14th District.

Providing meaningful mission assignments for the specially identified preventive patrol units referred to as strategic patrol units in Chapter 6 proved difficult. It is noteworthy that the St. Louis Police Department encountered the same problem in implementing the split-force concept.

The system model of the crime control function shows a comprehensive model of crime control. The model is not all inclusive since crime control activities of the criminal justice system and other parts of society are not included unless there is a definite interaction with the police. Chapter 3 discussed this model in greater detail and also offered a conceptual model for the overall criminal justice system.

Certain social, psychological, economic and environmental variables generate or maintain individuals in the population with a potential for criminal action. These same variables create states of the environment that provide some type of perceived gain for the member of the potential criminal population. The environment also alters the distribution of gain in time and space. As an example, the price of a Corvette is considered a state of the environment that provides a measure of gain to a criminal. A Corvette is more valuable than a Corvair. States of the environment also place the Corvette in an employee parking lot between the hours of 0900–1700 and in a residential area during the late evening and early morning hours. States of the environment are beyond the immediate control or influence of the police system. The conceptual model also accounts for crimes of passion, or crimes committed for psychological reasons. In these cases the gain is probably best described as emotional rather than material.

Given a state of the environment that offers a gain, an individual must then decide whether or not to commit and to execute a criminal event. The distinction between these receives elaboration later. This criminal event can be directed initially against property, as in burglary or theft, or against persons, as in rape or murder. In either case an individual becomes a victim. Unless the police detect the criminal event, this victim, another individual, or an alarm system must report the crime in order for the police system to respond.

Response to a reported crime is usually handled by the beat patrolmen. Later, a cold search by detectives may be undertaken as follow-up. Preventive patrol, however, is neither response nor follow-up. Preventive patrol is detection of the criminal, if preventive patrol failed to prevent the criminal event, without the alerting by an individual or alarm system.

Figure 5-1 shows two decision points for an individual: the decision to commit a crime and the decision to execute a crime. The decisions can occur simultaneously, or days apart, depending upon the criminal and the crime type.

The decision to commit a crime is undertaken when the state of the environment produces an opportunity which an individual perceives as a chance for material or psychological gain. The decision to commit a crime is also affected by the individual's estimate of the likelihood of apprehension and punishment, or deterrence. Past success in making on-view arrests by the preventive patrol force can act as a deterrent at this point, hence, the on-view arrest is seen as an instrument for crime prevention.

Deterrence is shown as an output of both the police and the courts and correctional instutitions. The perception of risk could be based on prior experience, knowledge of the criminal justice system or a unique and possibly distorted sense of the system's effectiveness. The decision to execute the criminal event is affected by an immediate perception of deterrence and the relative ease or immediate availability surrounding the commission of the criminal event. In summary, the decision to commit a crime depends on an individual's *a priori* assessments; the decision to execute a crime depends upon the individual's assessments of deterrence and availability in the immediate time and space surrounding the imminent criminal event.

Preventive patrol units must alter the immediate availability or the immediate deterrence factors so that the individual decides not to execute the criminal event. Failing this, preventive patrol must detect and apprehend the criminal. This latter action is assumed to alter an individual's perception of deterrence so that the individual, or other individuals learning of this result, will not decide to commit a crime in the future.

The state of the environment provides opportunities characterized in part by the degrees of availability or ease of committing a criminal event. As an example, a derelict sleeping in an alley offers more immediate availability for committing robbery than a man walking down a well-lighted street. A commercial establishment with an unlocked door after business hours offers more immediate availability than a securely locked establishment. Immediate availability represents specific invitations to commit a criminal event.

Deterrence comes in two parts: immediate deterrence perceived by an individual about to execute a crime, and deterrence based on an individual's overall perception of the criminal justice system which determines whether or not he will decide to commit a crime. In both cases deterrence is the perceived risk of punishment or personal injury. Technically, the courts and prisons punish; so the police can only increase the perceived risk of punishment by increasing the perceived risk of arrest. On-view arrests by preventive patrol units are assumed to increase the perceived risk of arrest, and are therefore considered a valid objective. Certain criminals, such as armed robbers, must consider the police capability to inflict injury or death since this criminal type sometimes provokes a gun battle.

Arrest constitutes a long term deterrent if the remaining parts of the criminal justice system (the prosecuting agency and the courts) promptly prosecute, convict, and sentence the criminals. This point is important since police patrol can identify and capture a criminal, but destroy the chance to convict, by illegal stop and search procedures. The legal procedures, then should provide constraints on the proposed tactics of preventive patrol. An improper arrest often will result in release of the criminal without any further action by the criminal justice system. This result probably will not have a sufficient deterrent effect on the criminal, assuming that the processes of the criminal justice system can act as a deterrent.

If the courts and correctional agencies choose to emphasize deterrence rather than rehabilitation, the decision is irrelevant to the preventive patrol function but not to the size of the criminal population. Rehabilitation is mentioned to assure readers that it has been considered.

It is, however, a judicial and correctional function. According to the President's Task Force report on corrections,[1] "Such treatment is often, though not always, less burdensome and unpleasant than traditional imprisonment. Rehabilitation efforts, therefore, may to some extent conflict with the deterrent goal of the criminal justice system." Unfortunately, little is known about the relative merits of deterrence or rehabilitation in reducing the criminal population.

In the preceding paragraphs, opportunity, deterrence and rehabilitation have been discussed with the intent of defining their use. The term "criminal event" has been used more frequently than the word "crime." Criminal event refers to a set of incidents or circumstances surrounding a crime that makes the criminal and the crime evident to the police

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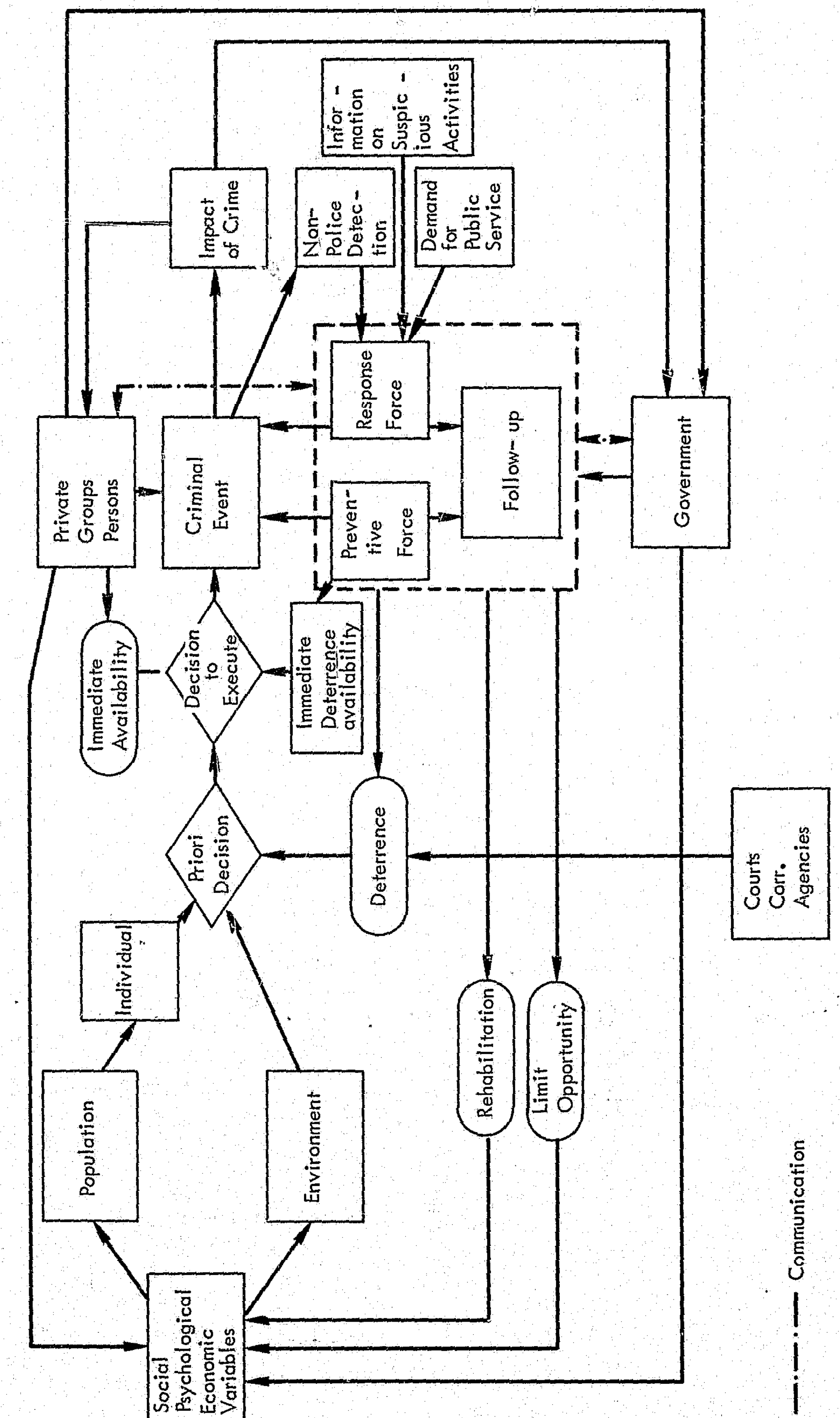


Figure 5-1 : Schematic of Police System Interaction

observer. The police observer might observe a burglar smashing a window to gain access, carrying stolen goods or reacting to casual police surveillance in a suspicious manner. In this case, the police observe the criminal. Perhaps the sight of a parked car at 0400 in a commercial area, or a broken glass window, will alert a policeman to investigate further and discover a burglary in progress. In this case, the police observe physical circumstances surrounding the criminal event and are thus led to detection of the criminal event. Since the response time is minimized by police detection, the probability of apprehension of the criminal is very high, but not unity. A 45-year-old policeman may observe a 14-year-old snatch a purse, but the ensuing foot-race may be won by the 14-year-old.

A British study[2] uses a different definition for detection. The reason is operational: ". . .in all cases covered by our data, whenever a crime was discovered by the police, it was always cleared up by the reporting officer, if it was cleared up at all." For purposes of eventual simulation, the Operations Task Force model wishes to isolate detection of the criminal event from apprehension.

The role of Preventive Patrol units centers on immediate availability and immediate deterrence. Specific actions which reduce immediate availability are premise checks, removing incapacitated persons from the street and enforcement of laws or or city ordinances, such as those forbidding motorists from leaving keys in the ignition of untended cars.

Cities and states can pass regulations which limit immediate availability and long-run opportunity for a criminal event by fining the potential victim. Such a person, for example, might be the individual who leaves an expensive camera in plain view on his car seat. Such ordinances could permit definite preventive police action. Otherwise, police can affect availability only through education of the public to the risks of negligent actions.

Reducing availability-opportunity as an approach to crime prevention might strike some segments of society as highly unreasonable. The point of mentioning this method is that it does exist in practice and in theory as one of the options for crime prevention. Cities, for example, often have a park curfew which is directed toward the prevention of crime. Some states will give a citation to the owner of a stolen car if the police discover that a key was left in the ignition. Insurance companies penalize customers who provide ample opportunity to criminals; the companies raise premiums or deny coverage altogether. If reducing the immediate availability deterred youth from becoming first offenders, the resultant saving to society would be enormous. At any rate, it represents an area for action by preventive patrol units if the ordinances are in effect.

It seems reasonable to assume that the police effect on deterrence is maximized by increasing the apparent likelihood of arrest for the criminal. In some restricted types of crime and with certain types of criminals (professional bank robbers), the police capability and readiness to use weapons affects deterrence. Unfortunately, the apparent likelihood of arrest does not deter all types of criminals. Chicago police clear more than 90 percent of the murders and 70 percent of the rapes, yet police universally regard these crimes as nonpreventable.

Another aspect of deterrence concerns how great the likelihood of arrest appears to the criminal. If deterrence is relevant, perventive patrol units can use different methods to increase the perceived risk to a criminal. As an example, the police can announce that an area will be covered by a number of men in plain clothes. Unless a great deal of publicity or success (on-view arrests) accompanies the influx of plain clothes officers, the tactic probably would not increase the perceived risk to a criminal. The same number of men in uniforms might increase the perceived risk since the revisit-time of a patrol would be cut. If, however, uniformed police do not have success in making arrests, they will not deter criminals either.

The apparent likelihood of arrest eventually becomes a function of both visibility and effectiveness. Even if the mathematics of detection and search theory show a low probability of arrest, a few publicized arrests could increase the perceived risk to a criminal over the actual risk.

The final role of preventive patrol is detection of criminal events. At least one source does not agree that this falls in the category of crime prevention; authors of the British study[2] speak of detection as a "good result" of police activity, but then they state, "detecting crimes and arresting or reporting the offenders is, in some ways, similar to preventing crimes like the possession of housebreaking implements, since detecting a crime seems to have little value in itself, the value being in the crimes prevented. Crime detection, as such, does not, therefore, appear to be a valid output to include in our measure, and it is rather the crimes that are prevented by virtue of detections that should be incorporated."

If one does not consider on-view arrests or detections as valid output to measure effectiveness, the crimes prevented (perhaps deterred or postponed) is the desired output. Unfortunately, this number seems difficult to measure. Apprehension is not considered here as a valid output of preventive patrol. Apprehension of a criminal does reduce the at-large criminal population, however, and provides correctional institutions with a chance to rehabilitate this particular criminal or to deter the criminal population general by its treatment of the particular criminal. On-view arrests can also increase the criminal's perceived risk of arrest and, hence, act as a deterrent for future crimes.

Many cities, in addition to Chicago, have specialized units devoted to preventive patrol. In a larger sense, the entire police system is supposed to prevent crime. The arrests resulting from the investigative efforts of detectives add to the overall deterrent effect of the police. This latter type of response, however, is not universally effective against all types of crime. Crimes against property, when committed without human observation, have very low clearance rates. The role of preventive patrol units in these crime areas is to appear as an effective detection and apprehension system. In addition, the units can lower the immediate availability of a location by conspicuous and effective premise checks and by educating potential victims to the threat.

Preventive patrol units are aimed at the prevention of visible crimes, such as those committed on streets, in public conveyances and in areas where police can patrol. Beat cars, responding to calls for service, do not have enough continuously available time to execute effective patrol plans. It is not claimed that only special units perform preventive patrol, but but it may well be that effective amounts of preventive patrol can be administreed best with special units.

Preventive Patrol Activities

The term Preventive Force includes, in general, all police field resources in service that are not specifically designated to respond to calls for service. In Chicago, the preventive force is composed of the Patrol Division Task Force, District Tactical Units, Patrol Division resources assigned to police districts while they are on preventive patrol and of elements of the Detective Division and Vice Control Division when they are in an unassigned status. In this chapter, specific attention is given the Patrol Division Task Force. At the present time, the Task Force is the largest permanent component of the Preventive Force.

The Preventive Force, as its name indicates, is employed to prevent crime. While the output of every unit of the police department is directed in some manner towards the overall fight against crime and, hence, crime prevention, units such as the beat patrolmen and detectives usually respond to a criminal event. Ideally, this response will prevent future crimes in some manner, but, has not prevented the criminal event requiring this response. The Preventive Force attempts to prevent crime by patrolling an area, investigating suspicious persons or circumstances and checking the security of likely targets of criminal attack.

The goal of crime prevention is unquestioned; however, it seems prudent to investigate types of crimes, locations of crimes, and legal restrictions associated with preventive activities of police units. The Preventive Force, represented generally by the Task Force, performs patrol. The Task Force patrols streets, alleys, parks, public buildings and other public areas. While laws differ in various states, the police are generally restricted from patrolling private areas unless there is strong evidence that the law is being broken or a clear danger to life exists. Under these circumstances, however, the police are responding to a criminal event, not preventing it. Thus, the crime prevention role of the Task Force is restricted to public areas which can be viewed by police in a patrol car.

Crime prevention by a Task Force unit is directed toward street crimes such as robbery, assault, and auto theft, or crimes which may be detected in progress when forced doors, broken glass, or stolen property are observed. The major crimes of murder and rape are most often committed in regions denied to police patrol. Most categories of white collar crime, such as tax evasion, consumer frauds, usury and embezzlement, cannot be detected or prevented by Task Force patrol. Similarly, only the overt actions at the lowest echelons of organized crime, such as vice activity and narcotics traffic could be affected, by preventive patrol. Normally, Task Force units are considered successful if they detect a criminal event in progress. Some argue that this is not crime prevention, but instantaneous response. This point will be discussed later.

Task Force units can make arrests and claim that the activity prevents a more serious crime. Examples include arrests for possession of burglary tools, carrying a concealed weapon, possession of an unregistered firearm and possession of dangerous drugs or narcotics. These arrests, however, require stop and search actions.

In Chicago, a police officer can frisk a person for a weapon and examine the interior of a car if he suspects imminence of deadly attack. People and vehicles can be stopped if they fit descriptions of persons or vehicles involved in a reported crime. Routine license checks and name checks during the issuance of a citation for a traffic violation can also result in an arrest if the vehicle is stolen, or if the man is wanted. This type of emphasis on crime prevention requires an aggressive patrol strategy of frequent traffic stops, stop-and-frisks, and street stops with license checks. Since the high street crime areas are often characterized by poor socioeconomic conditions and populated by minority groups, some activities associated with preventive patrol are viewed as harassment by minority groups.

If aggressive preventive patrol is not used, the Task Force either relies upon visible deterrence to prevent crime, waits for a crime to occur in its presence or responds to a reported crime to make an arrest. The only mechanism of crime prevention becomes deterrence, the risk, as perceived by the criminal, of capture or injury by police.

What actions can the Task Force take?

We have discussed aggressive preventive patrol with emphasis on stopping suspicious persons and vehicles. The Task Force could also conduct high-intensity patrol. This is a strategy which seeks to deter a criminal by an obvious display of intense patrol activity where the patrol units used marked cars and wear uniforms. If patrol units used unmarked cars and wear plainclothes, the emphasis is on arresting a criminal in the act. If this tactic is publicized, it may also deter crime in an area. High intensity patrol has been effective, but the number of units necessary limits the area of coverage or the amount of time a particular area can receive intense coverage. High intensity coverage may be more acceptable to minority groups since vehicle stops with the accompanying search and frisk would be less frequent. The police units would spend more time on patrol and would have more time for premise checks. Arrests for carrying concealed weapons, possession of narcotics, persons wanted on warrants, and possible auto theft naturally would decrease. The choice between the two tactics may be dictated in particular cases. For instance, during periods of high racial tension, the saturation strategy with less direct confrontation between police and citizens would probably be less abrasive than aggressive patrol.

A third type of preventive patrol can also be identified. It is a form of stake-out or fixed-point defense. Foot beats, stationing police in subway stations, guarding banks, and placing police on subway trains and busses are all examples of this type of deployment. Foot beats are the most costly type of deployment since the area of coverage is very small, and the general usefulness of these police officers to support other officers in a coordinated action is drastically limited by the lack of mobility and communication. (The communication problem is eased if personal radios are in use.) This type of patrol can also change the emphasis from deterrence to arrest by the use of plainclothes officers. Philadelphia has used a random placement tactic of stake-out teams at banks. The units operate in plainclothes and never announce which banks will be covered. This tactic has been successful in decreasing the incidence of bank robberies within the city limits of Philadelphia.* The use of this type of deployment is justified only when the area offers a great opportunity to criminals or if criminals have repeatedly operated in the area.

In the preceding discussion, three types of preventive patrol deployment have been mentioned: aggressive preventive patrol, high intensity patrol, and a form of stake-out. The choice of deployment depends upon the number of patrol units available, police knowledge of criminal intentions, the type of crime which the police wish to prevent or suppress, acceptance by the public and whether the police desire to deter crime by a visible presence or by demonstrating success in capturing criminals in a criminal act.

Competition for manpower exists within the police department. The establishment or enlargement of a preventive patrol force must consider the benefits to the police department, and the community, if the manpower were used to increase the response force, the detective force, police community workshop efforts, or a non-police function with the city government structure. Ideally, the material in this chapter should facilitate an analysis of the trade-off between the preventive patrol force, the response force and a detective force to obtain the optimum mix of these forces. The measure of comparison would be the probability of arrest or some measure of crime deterrence. In addition, community service aspects of the response force and the benefits of the recovery of stolen property by the detective force would also need to be considered when allocating manpower a police department.

*The Evening Bulletin, Philadelphia, Pa., "Stakeout Squad 4 Years Old; Rizzo's 'More Than Pleased'," 9 September 1968, p. 13, Section B.

Unfortunately, time did not permit field verification of the patrol models discussed here. For this reason, manpower tradeoff between different usages that are based only on the probability of arrest could not be determined. This suggests further work, particularly to permit structuring a resource analysis budget. The analysis in this chapter should assist in identifying trade-offs between different deployments of a preventive patrol force. In short, if a police department either has a preventive patrol force or contemplates establishing a preventive patrol force, this chapter should help achieve maximum effectiveness. The analytical methods estimate the probability of placing a police unit at the same location during a criminal event or immediately preceding a criminal event. If this probability is maximized, the police have the best opportunity to effect an on-view arrest or to deter a criminal action. The relative amount of discussion given each type of deployment reflects its amenability to analysis and the amount of time devoted to its study.

No attempt was made to assess the community value of each type deployment. As a qualitative judgment, departments should insure the adequacy of the response force before structuring a preventive patrol force. For major departments, this chapter provides a discussion and analysis of methods of deployment which improve effectiveness.

DEPLOYMENT OF PREVENTIVE PATROL UNITS

The Challenge of Crime in a Free Society[3] states:

> "Preventive patrol— the continued scrutiny of the community by visible and mobile policemen—is universally thought of as the best method of controlling crime that is available to the police. However, the most effective way of deploying and employing a department's patrol force is a subject about which deplorably little is known."

The goal of this section is to state conclusions and recommendations for the deployment of preventive patrol units. The detailed mathematical development and the resulting computer programs are described in a technical section at the back of the chapter.

The Challenge of Crime in a Free Society further concludes that a patrolman would observe a robbery-in-progress only once in fourteen years. A more detailed analysis supporting this assertion is presented by Blumstein and Larson.[4]

This result was based on a condition where crime and police are uniformly distributed throughout a city having twice the area of Chicago and a police force half the size of the Chicago Police Department. Without challenging the assumption of uniform crime distribution, Chicago could anticipate a fourfold improvement based solely on area and the number of police.

The point remains, however, as to a level of on-view arrests that police administrators expect when forming a preventive patrol unit. The overall role of a preventive patrol unit considers outputs other than on-view arrests. When planning deployment, however, the probability of achieving an on-view arrest should be maximized. The probability of space-time coincidence or the probability of placing a preventive patrol unit at the same place and time as a criminal event should be maximized. No contradiction exists; the position is taken that this action will also provide maximum deterrence, reduce response to crime in progress calls and place preventive patrol units in the areas most susceptible to police actions intended to reduce opportunities for criminal acts. Thus, while the probabilities of space-time coincidence for representative numbers of preventive patrol units will never be large, they will be maximized to improve the overall effect of preventive patrol.

MAXIMIZING SPACE-TIME COINCIDENCE

Computer simulation of a preventive patrol force in Chicago was the tool used to estimate the probability of space-time coincidence. The effort assumed a uniform distribution of crime throughout the city and used simulation to determine the number of units in patrol status when a robbery was reported. In the simulation, both actual times of a robbery and the actual number of units in patrol status were used when computing the probability of space-time coincidence.

Analytically, there is a difference in the probability of space-time coincidence for units assigned to a specific sector or if more than one unit can patrol the same area. When specific sectors are not assigned, two or more units could arrive at a location at the same time. This results in overlapping patrol activity and a reduction in the probability of space-time coincidence for the total number of patrol units. This is generally referred to as an exponential saturation law of detection. In this report, space-time coincidence rather than detection is the output objective. For illustration, a comparison of the assigned sector and the non-assigned sector methods is shown in Figure 5–2. The dashed line indicates where little difference exists.

The miles of streets and alleys in the section of the city used in the preventive patrol simulation were considered in the model for computing the probability of space-time coincidence described in the technical detail. This simulation considered robbery and the probability of space-time coincidence as a function of the number of miles of streets and alleys, the assumed time that elements of a robbery are visible to patrol units, and the assumed speed of patrol. As such, Figure 5–3 is specialized.

But it demonstreates that little difference exists between the linear and exponential saturation laws under these conditions. It also shows the probability of space-time coincidence against the crime of robbery as a function of manpower. As a reference point, the probability of space-time coincidence for twenty patrol units is shown as less than 0.010. If ten robberies occurred in this region per day, the expected number of space-time coincidences would be nearly 0.10, or about one every ten days. This number is given for comparative purposes; it assumes a uniform distribution of crime and police.

Uniformity is not a very good assumption. A computer program incorporating the exponential saturation model for random patrol, a method for assigning patrol units to regions in a manner to maximize the probability of space-time coincidence, and a subroutine which groups events occurring in a larger region into small rectangular cells is described later. The analysis showed a clustering of robberies within several high crime areas of the city. In one of the highest crime areas, robbery data for a period of three weeks grouped in approximately one-half of the area.

The grouping of crime data to determine the most likely rectangular cells for a crime occurrence, followed by allocation of men to these cells in a manner to maximize the probability of space-time coincidence, demonstrates a potential result, not an actual result. This occurs because assignments are made on the basis of historical information—hence perfect information. A more valid test would assign men to cells of the highest predicted probability, and then compute the probability of space-time coincidence on the basis of actual criminal activity. Under these test conditions, the potential value of the space-time coincidence with twenty men reached 0.0265 for the same region. This value is not directly comparable to the value obtained from Figure 5–3 since they were calculated differently. The values should be compared, however, when estimating the relative effectiveness of preventive patrol in achieving space-time coincidence using different deployments. In another area of the city, the probability of space-time coincidence attained 0.0515, approximately five space-time coincidences every ten days for twnety units in service. More than tenfold improvement could be gained by changing the size of the cells and the number of units in each cell.

The relative increase in space-time probability warrants attention. In some sectors of the city, certain crimes may not cluster. Preventive patrol units should probably not be deployed in these sectors. Similarly, preventive patrol may not be effective against certain types of crimes which do not cluster in space.

Two probabilities enter into the allocation of preventive patrol units. One is the probability that a crime will occur in a particular region, and the second is the probability that a preventive patrol unit will achieve space-time coincidence when patrolling the region where the crime occurs.

The allocation of men against street robbery and the allocation of plainclothes bus riders against bus robbery was considered. The first instance concerns allocation of men to likely cells of criminal activity where the probability of achieving space-time coincidence in a given cell is dependent on the number of units in the cell. In the second instance, space-time coincidence is achieved only when a rider is on a bus when the robbery occurs. The problem in bus robbery concerns the choice of the targets to protect. This is a typical fixed point defense. In the street robbery strategy which uses random patrol units, space-time coincidence is not guaranteed even if units are in a cell where a robbery occurs. The method for deploying preventive patrol units is given below:

(1) Rank the probability of a crime occurring in a specific sector, bus, location in decreasing order.

(2) If a stake-out (bus rider) is used for this location, multiply the determined probability by unity to obtain the probability of space-time coincidence.

(3) If a sector or cell is to be covered by random patrol, use the probability determined by a program similar to the one presented here. The probability of space-time coincidence can be obtained, given that the crime occurs in the sector, and given a specified number of men in patrol status. Multiply the determined probability by the probability of achieving space-time coincidence.

Figure 5-2 : Differences between Linear and Exponential Saturation

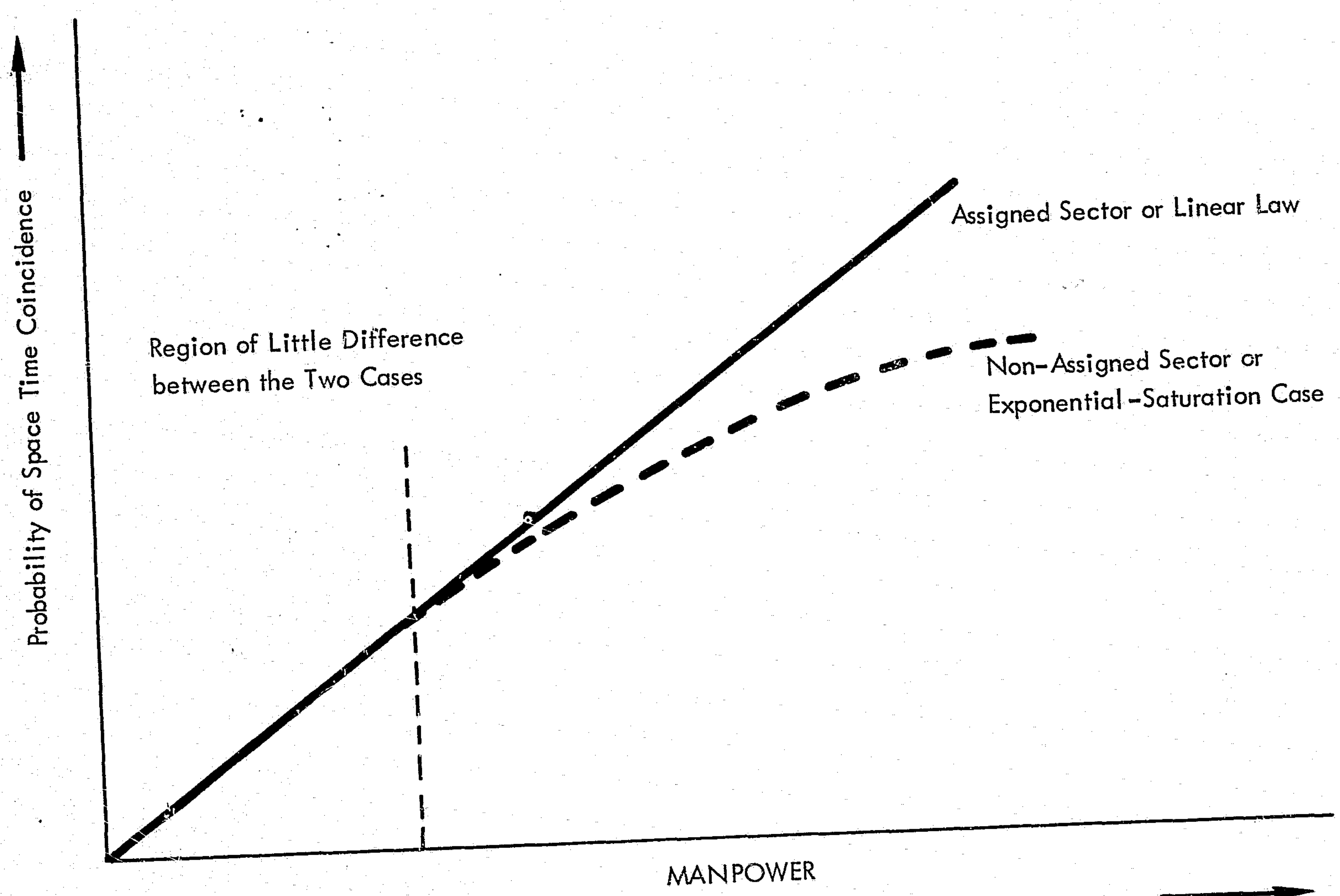
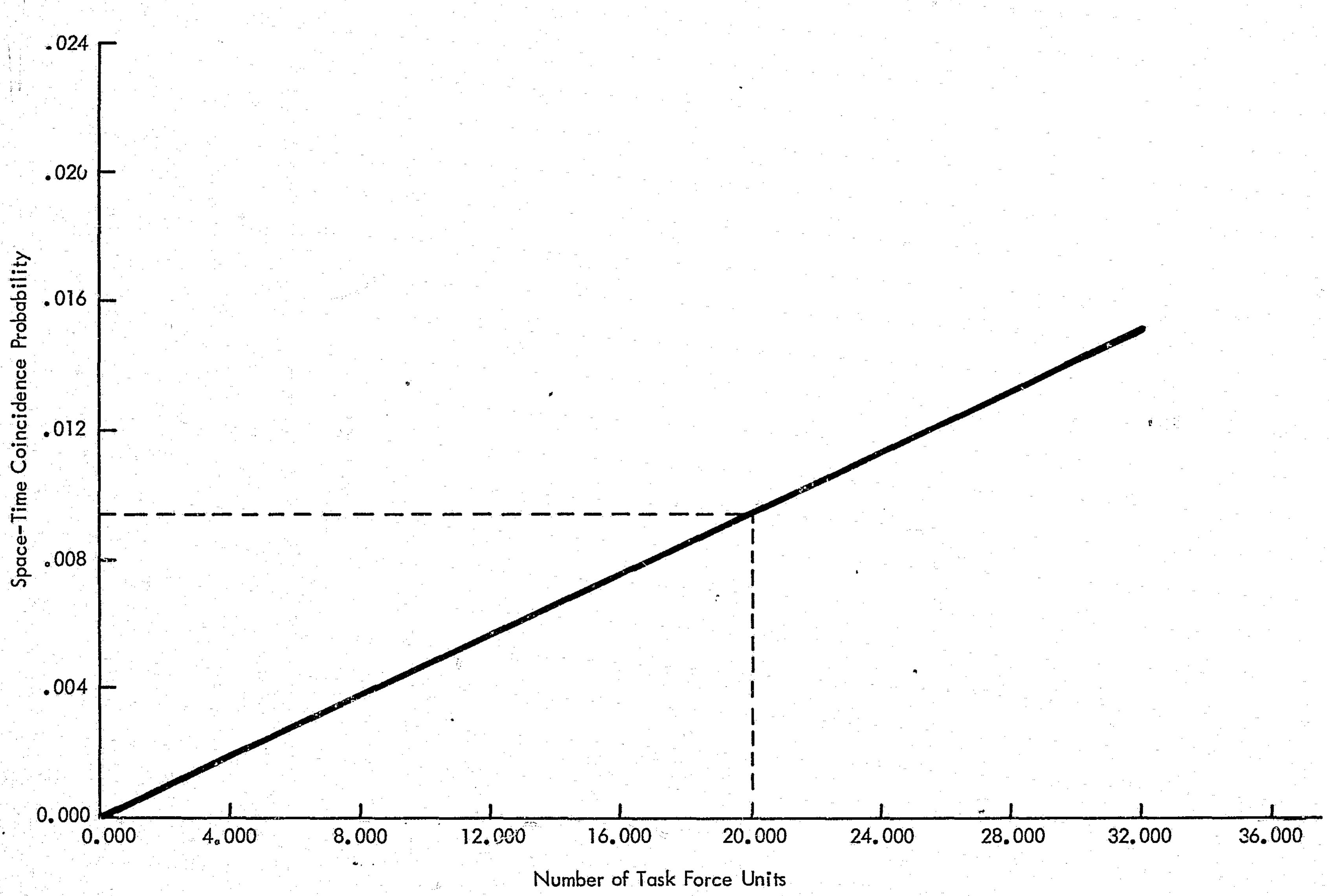


Figure 5-3: Comparison of Linear Saturation Versus Exponential Saturation for Random Patrol.



(4) Rank the products computed in (2) and (3) in decreasing order.

Deploying preventive patrol manpower to the places in order of this ranking will result in the most effective placement of men to maximize the overall probability of space-time coincidence. In addition to considering effectiveness, a police administrator should consider the importance placed on specific crimes by citizens when prescribing deployment. While citizens regard murder as the most important crime, it cannot be significantly affected by preventive patrol. Therefore, the police administrator should consider only crimes amenable to patrol when weighing his allocations by citizen reaction. The scores for different crime types are taken from Selin and Wolfgang's *The Measurement of Delinquency*[5] which used a survey of university students, police officers, and juvenile court judges to develop scores. For the same amount of money ($10–$250) and with no injury to the victim, the survey gave scores of 6, 4, 3, and 2 for armed robbery, strong-arm robbery, burglary, and auto theft (auto recovered undamaged), respectively. Ranked probabilities of space-time coincidence depend upon the type of crime. If the ranked probabilities are multiplied by the Selin-Wolfgang score and then re-ranked, the result is an allocation of preventive patrol units based both on citizen concern and the ability of the police to achieve space-time coincidence.

The methods for allocating preventive patrol resources discussed in this chapter were employed to a limited extent in the study of Patrol Division Task Force Activity in the First Area, in the study of Robbery in the 2nd District and in the evaluation of the effectiveness of preventive patrol during the administrative experiment in the 14th District.

The near capacity commitment of computer facilities of the Chicago Police Department precluded introducing additional computer programs to which could furnish timely, periodic information relating to clustering and geographic transition of specific crimes as well as to suggested preventive patrol assignment to the commander of the Task Force and district crime coordinators.

When the Chicago Police Department obtains its third generation computer, it will be possible to expand the methods developed by the Operations Research Task Force and provide planners with necessary material to determine increasingly effective deployments. Thus, within about one year, there should be many opportunities to test efficacy of assignments in the field.

With the prospect of being able to provide the necessary information at some future time, the evaluation scheme devised for the administrative experiment in the 14th District takes on added significance. One of the most important aspects of the quantitative measure chosen is that it allows comparison of patrol operations in a district pursuant to one policy with operations and policies in the same district at other times. Such comparisons made weekly could constitute a time series.

MEASURES OF EFFECTIVENESS

The criterion for selecting the best allocation of preventive patrol resources has been the probability of space-time coincidence. The reasons for selecting this measure have been stated previously. In the practical sense, the police are interested in whether they increase arrests or whether crime does down. Citizens are interested in whether they are subject to a high risk of victimization. Within the police system, the preventive force should be allocated to units which best reduce the victimization rate, which is what the public is really concerned about. Lowering the victimization rate may or may not involve an increase in arrests; but it certainly involves a decrease in the amount of crime per hundred thousand of population (a measure of the victimization rate).

If attention is constrained to the preventive patrol force, the measures of effectiveness center on the number of arrests and the total amount of crime. The police can only evaluate their efforts to reduce crime by comparing the amount of reported crime in a particular category to that of a comparable period. In some crime categories only one-half of the actual crimes are reported to the police. A change in public behavior concerning crime reports could potentially double the number of crimes known to the police.

Besides the problem of crime reporting, comparisons from one period to the other on reported crime must be made with seasonal adjusted data, unless a period is compared to the same period last year. In this case, the trend must be isolated. Usually, police management wants to learn whether a change in procedure is beneficial as quickly as possible. Comparing pre-change and post-change periods merely on the basis of reported crime, then, has many complications.

Previous discussion of preventive patrol asserts that police initiative, or preventive patrol, can occur in basically three ways: (1) reducing the immediate availability for a criminal event, (2) increasing the

apparent likelihood of arrest to a would-be criminal (deterrence) or (3) detecting the criminal event and apprehending the criminal. Different tactics of preventive patrol would alter the emphasis given to any one of these activities, or vary the manner in which the activities are undertaken. The measurable quantities of reported crime and the number of arrests resulting from the detection of a criminal event reflect the success of these activities.

If preventive patrol tactics are effective in the first two activities, crime should decrease. Success in the third area will obviously increase the number of on-view arrests. (On-view arrests can arise from two sequences of events: detecting the criminal event and identifying an individual as the criminal and placing him under arrest, or observing a suspicious person or circumstance and linking the person to a criminal event. These sequences of events take place within seconds or, at most, minutes of each other in the context of an on-view arrest). The activities are obviously interrelated. A decrease in crime will reduce the number of arrests and, hopefully, increase on-view arrests. This will reduce crime by removing criminals from society and by acting as a future deterrent on the criminal or his criminal acquaintances.

During World War II, operations research workers needed measures of effectiveness to compare operational performance with theoretically achievable performance. In addition, measures of effectiveness were used to compare different means of attaining the same ends. One example concerned the operational sweep rate used to describe the effectiveness of different search units. The operational sweep rate was written as:

$$Q_{op} = \frac{CA}{NT} \qquad (1)$$

where:

Q_{op} = operational sweep rate
C = the number of enemy contacts
A = the area searched
T = the total time spent by the search unit in area A
N = the probable number of enemy units in the area.

In using this equation, everything can be measured quite precisely except N, the probable number of enemy units in the area. This number was based on various intelligence estimates.

A similar problem exists with crime statistics. Police know the number of reported crimes in the area. The amount of actual crime, however, is not known by the police. Non-reporting of crime is mentioned in reference,[1] and the amount of non-reported crime varies with crime type. The National Opinion Research Center of the University of Chicago surveyed 10,000 households on a nationwide basis, asking whether the person questioned or any member of the household had been a victim of crime during the past year. Fewer than one-half of the crimes uncovered by NORC were reported to the police. Tables printed in Crime and Its Impact: show that the amount of personal injury crime reported to NORC is almost twice the Uniform Crime Report (UCR) rate prepared by the FBI. The amount of property crime was more than twice the UCR rate. As an example, the percent of cases in which police were NOT notified for robbery, aggravated assault, simple assault, burglary, and auto theft as 35%, 35%, 54%, 42%, and 11% respectively.

Therefore, the wealth of police statistics provides only an estimate of the actual crime rate. Increased confidence in the police ability to solve crimes or the police ability to protect the victim from reprisal could substantially increase the amount of reported crime. In the categories of robbery, aggravated assault, simple assault, and burglary, the number of non-reported cases would potentially decrease by 45%, 38%, 42%, and 65%, respectively.[7] Thus, improved police service could cause a large rise in the amount of reported crime. Clearly, then, the amount of reported crime is a poor measure of effectiveness unless the analyst knows that the ratio of reported to non-reported crime is relatively constant. This means that deterrence is nearly impossible to measure directly, unless surveys similar to NORC are undertaken for this purpose.

The reason for introducing Equation (1) is to propose a measure of effectiveness which couples the observables of on-view arrests and reported crime with the objectives of preventive patrol. Consider a redefinition of Q_{op} where

C = Number of on-view arrests.
A = The areas patrolled.
T = The total time spent by patrol units in area A.
N = The amount of reported crime during time period T in area A.

and

$$Q_{op} = \frac{CA}{NT} \text{ as before.}$$

The ratio of C/N gives an indication of the effectiveness of the patrol tactics in catching criminals.

The incorporation of the area and the time of patrol activity shows the effect of patrol unit density. Even the effects of reducing the immediate availability and increasing the apparent likelihood of arrest will appear in equation (1)—if the effects are measurable in light of the nature of reported crime. A reduction in reported crime N will increase Q_{op}—as will an increase in the number of on-view arrests. So, the effects of the three activities of preventive patrol will increase the number, Q_{op}, if the activities increase on-view arrests or result in a reduction of reported crime. If a large shift is observed in Q_{op} by a change in preventive patrol tactics, the change is probably significant—even if the ratio of reported to non-reported crime is changing.

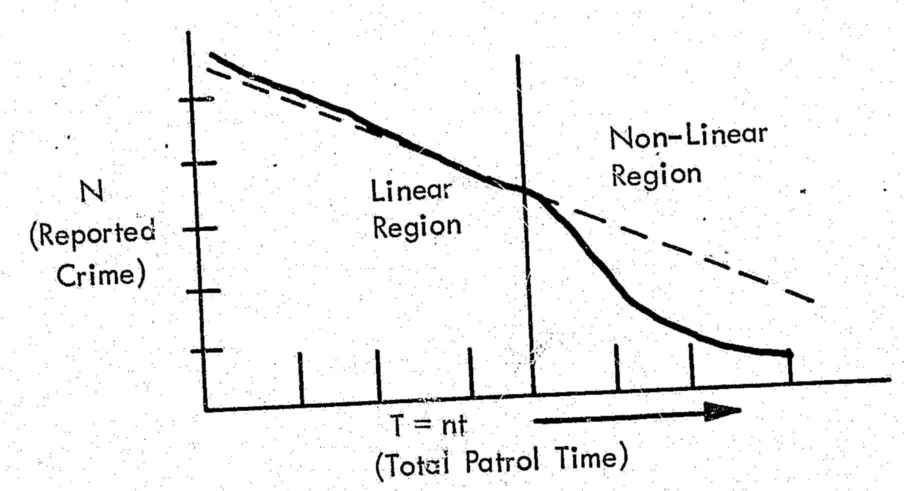
The exact form of Q_{op} can vary depending upon the intended purpose of the measure. If different tactics for a given police district are veing evaluated, no numerical value of A is necessary. If different districts are being compared, or if Q_{op} is being compared to some theoretical model of a preventive patrol search rate, a numerical value for A is necessary. The type of crime and the nature of patrol will indicate whether an area measure or a measure of the miles of streets and alleys is more relevant. While the ratio measure, Q_{op}, gives a box score result, the number should be used with a separate enumeration of C and N. This permits the reader to determine whether Q_{op} increased as a result of deterrence or on-view arrests. Also, comparisons with large differences in the number of patrol units are suspect. For instance, the deterrent effect is probably not a linear function of the number of preventive patrol units. Suppose reported crime varied as shown in Figure 5–4.

A comparison of Q_{op}'s with T in the non-linear range would not necessarily show a difference in tactics *per se*, but rather the effect of increasing the density of patrol units. Unless N and T are known to vary in a linear manner throughout a wide range, a comparison of tactics should be done only when the T's are close in value.

The measure of effectiveness, Q_{op}, probably should be applied to specific crime categories, strong-arm robbery, auto theft, etc., rather than overall crime. One type of preventive patrol, by nature of the time and place conducted, could be very effective against one crime type and ineffective against another crime type. Testing this tactic by using figures of overall reported crime could mask its particular virtues against one type. Of course, actions that deter burglars could also deter robbers, and the additional benefit would not be measured in this manner.

It would be highly desirable to graph Q_{op} as a function of T (the number of patrol units $n = T/t$ could also be used as a parameter where t is the time

Figure5–4 : Hypothetical Relationship between Reported Crime and the Total Patrol Time.



$T = nt$ (Total Patrol Time)

n = number of preventive patrol units

t = amount of patrol time per unit

of search for one unit) in an effort to describe the degree of improvements as a function of manpower. This could provide estimates of marginal productivity as a function of the tactic and the manpower already committed.

Preventive patrol forces also participate in other police functions such as emergency responses, fast reaction to civil disorders, felonies in progress, and the recovery of stolen property. The recovery of stolen property is a measure in itself. Certain aggressive patrol tactics which use traffic stops as a means of initiating a personal and auto search for weapons are also self-measuring, namely the number of weapons confiscated.

The measures of effectiveness discussed here deal specifically with preventive patrol units. The citizens of a community, however, may be less interested in the arrest to crime ratio, or the percentage increase in crime, than in the victimization rate: namely, how many persons per hundred thousand will be victimized in a year. In the long run, preventive patrol will decrease the victimization rate if Q_{op} continues to increase. In this regard, the chosen measures of effectiveness for preventive patrol units are consistent with a measure of effectiveness for comparing different communities.

To summarize, this paper asserts that preventive patrol should decrease crime or increase on-view arrests. The use of Q_{op} provides a box score type of a measure of effectiveness for these objectives. If police management considers the recovery of stolen property, or the confiscation of weapons important ends in themselves, their numbers serve as the measures of effectiveness. If these latter activities have any relevance to the commission of crimes, the resultant value of Q_{op} will reflect this relevance.

Q MEASURE APPLIED TO THE 14TH DISTRICT

This experiment split the men assigned as beat officers into two forces. One force was assigned to answer calls for service in the same manner as previously. The other force did not receive radio assignments from the Communications Center but conducted preventive patrol. When the first force, the response force, was not answering calls for service, it also was supposed to conduct preventive patrol. While the total time for preventive patrol was expected to increase, the major difference was that some units spent all of their time on preventive patrol and would thus be expected to be more effective.

A modification of Q_{op} was used.

$$Q = \frac{C}{NT}$$

C was the number of patrol arrests, N was the number of reported crimes and T was the total amount of time for preventive patrol activity. Arrests were taken for all criminal offenses and also separated by crime type—as were the reports of crimes. The Q statistic was run for one week periods.

The total available time for preventive patrol was computed by multiplying the total units assigned for a twenty-four hour period by seven days and by seven hours. The normal watch is eight hours, but previous study in the district showed that lunch, personals, and car service reduced the available time of a unit by an average time of one hour. The time out of service for answering calls is recorded and keypunched on IBM cards each time a beat car is dispatched. This has been a normal procedure for several years in Chicago. The total time out of service, as obtained from these records, was then subtracted from the amount of available time. In formula form:

$$T = (\text{units} \times 7 \text{ hours} \times 7 \text{ days}) - (\text{Service time on calls})$$

Table 5–1

Q Values for Different Crime Categories*

Overall criminal	Robbery	Serious assault	Burglary	Theft	Auto theft	Miscellaneous criminal
1968 MEAN						
78.938	61.047	270.646	40.441	66.859	31.852	102.229
1969 MEAN						
84.386	50.186	205.571	41.792	64.636	34.918	118.355
1968 STANDARD DEVIATION						
14.757	64.476	177.450	20.104	29.967	21.546	22.727
1969 STANDARD DEVIATION						
16.098	70.657	112.110	25.645	34.096	18.195	29.626

* 1968 values are based on a sample size of 11 weeks while the 1969 values are based on a sample size of 12 weeks. The values of Q are always less than unity in these samples. The actual Q value is multiplied by 10^5 for easier comparison. There are 21 degrees of freedom.

Table 5-2

Analysis of Change in Q Values From 1968 to 1969

	t Test	Change significance
Overall crime........	−0.8061	None of the changes can be considered as significant at the 5 percent level.
Robbery...........	0.3668	
Serious assault.......	1.0132	
Burglary...........	−0.1335	
Theft..............	0.1581	
Auto theft..........	−0.3533	
Miscellaneous criminal..........	−1.3903	

Thus, Q is adjusted each week if unusual demands alter the amount of time for preventive patrol.

For twelve weeks in 1969, the summer of the 14th District experiment, Q was computed for overall crime, serious assault, robbery, theft, auto theft, burglary, and miscellaneous criminal offenses. (This latter category unfortunately lumps various crimes such as criminal trespass with more serious crimes such as kidnapping, treason, arson, fraud, etc.) For corresponding weeks during the summer of 1968, the same Q values were computed. The means and standard deviations for each Q category for 1968 and 1969 were computed. A Student's t-test was used to determine if significant changes occurred between the Q values of 1968 and 1969. Table 5-1 summarizes these Q value results and Table 5-2 gives the results for the Student's t-test and the F-ratio tests.

The mean values of Q for 1969 increased over the mean values of Q for 1968 in the overall criminal, burglary, auto theft and miscellaneous criminal categories. The Student's t-test, however, does not permit us to reject the hypothesis at the 5% significance level that no change occurred. This same result holds for those categories where the Q value of 1969 was worse than that of 1968. In short, the experimenter cannot assert that the different procedures of 1969 caused either an increase or decrease in the Q values for any of the crime categories.

Table 5-3

A Comparison of Preventive Patrol Time for 12 Weeks in 1969 and 11 Weeks in 1968

	T, average hours per week	Standard deviation	Minimum weekly value (hours)	Maximum weekly value (hours)
1969........	1004.15	169.36	831.75	1255.72
1968........	876.74	67.16	768.77	981.57

One of the major aims of the 14th District experiment was to either increase the actual amount of preventive patrol time, or to permit longer intervals of time for specific units to conduct preventive patrol. These two objectives were achieved. In 1968, forty-six units were assigned for patrol duty every twenty-four hours. In 1969, this number was forty-nine. After subtracting the amount of time spent by the units in responding to calls for service, the average time available for preventive patrol increased by an average of approximately 125 hours per week. Table 5-3 summarizes the comparison of preventive patrol time, T, for 1968 and 1969 in terms of weekly values.

Since some of the units in 1969 were not assigned radio calls for certain time periods of their watch, both the actual number of hours for preventive patrol was increased as well as providing uninterrupted periods of time for preventive patrol. Table 5-4 shows the average number of arrests per week for 1968 and 1969. For the sixth, seventh and eighth police periods of 1968 and 1969, the calls for service in the 14th District for different crime categories are listed in Table 5-5.

These categories do not all correspond to headings in Tables 5-1 and 5-2 because the radio call card data for miscellaneous criminal events and overall crime were not summarized in the same manner. The major point, however, is that reported incidents increased in all categories used in the Q calculations. This does not necessarily mean that deterrence is absent, since the trend might have been decreased. The percentage increase, however, runs about 10% in all categories except rape, auto theft and theft in the 14th District for these three periods.

From this example, it appears that the difficulty in making meaningful mission assignments for the strategic patrol made it impossible to exploit the substantial amount of additional preventive patrol effort.

The drawbacks of Q with its dependence on N, the level of reported crime, has been mentioned. Q in 1969, all other things being equal, would increase

Table 5-4

A Comparison of Arrests for 12 Weeks in 1969 and 11 Weeks in 1968

	Average number of arrests per week	Standard deviation	Minimum weekly value	Maximum weekly value
1969.......	33.73	5.80	25.00	42.00
1968.......	27.18	5.91	19.00	37.00

Table 5-5

Calls for Service by Category in District 14

Police period (1969/1968)	Robbery	Serious assault	Burglary	Theft	Auto theft	Total index crimes
6..........................	34/ 31	33/18	209/174	68/ 72	173/119	523/ 417
7..........................	50/ 32	23/21	194/205	59/ 53	128/168	455/ 483
8..........................	51/ 41	24/24	213/162	65/ 62	127/140	487/ 434
Total (3 periods).........	135/104	80/63	616/541	192/187	428/427	1,465/1,334

if the ratio of reported to unreported crime decreased. Over the last few years, calls in Chicago from citizens have increased by nearly 10% per year. The population has declined slightly during the same period. Therefore, the citizens do not appear reluctant to seek police action, and it seems safe to assume that the ratio of reported to unreported crime has not decreased to any significant degree from 1968 to 1969. The major objective of the experiment was to increase T during the experiment. With the increase in T, Q would decrease in 1969 in the 14th District if arrests did not increase, or if crime did not decrease. As mentioned earlier, the statistical test on the weekly Q values showed no significant differences between 1969 and 1968. The increase in T and the increase in reported crime-calls for service would have decreased Q unless the number of arrests increased. Table 5-4 does show an increase in arrests during 1969. This increase only offset the other variables tending to decrease Q. With more time for preventive patrol and with an increase in criminal activity, arrests would be expected to increase. The increase, however, was insufficient to demonstrate an improvement in the Q ratio. Thus, by this measure, the experiment which increased preventive patrol time did not increase preventive patrol effectiveness.

If Q in the 14th District were to be compared with another district, a measure of the area of patrol—such as square miles, or miles of streets and alleys—should be used. In other words, Q_{op}, as given in equation (1) permits comparison with other districts. Care must be taken if the types of crime or the types of buildings are different. For instance, a comparison of Q_{op} for burglary in two districts would be doubtful if all the burglaries in one district were commercial and burglaries in the other district were primarily residential. A more valid comparison in this case would be arrests and reported incidents of commercial burglaries with A limited to portions of the districts zoned for commercial property. The measure of Q_{op} holds great potential, but the analyst must beware of its invalid application.

Chapter 6 describes all aspects of the Fourteenth District experiment in much greater detail.

BURGLARY AND AUTO THEFT IN 20TH DISTRICT

A study was undertaken to determine methods of improving the effectiveness of police patrols against auto theft and burglary. It was decided to focus on these crimes rather than study all crimes amenable to patrol because of the short duration of the study. Auto theft and burglary were chosen because of their high incidence. The data on these two crimes city-wide is voluminous, so District 20 was designated the area of concentration. The techniques used in the study and the suggestions for improving patrol effectiveness in District 20 can be applied with suitable modification to any district in the city.

The patrol cars currently respond to calls for service as well as patrol aggressively to prevent crime. Under consideration by the CPD was a split patrol force. The A-patrol force would be dedicated to the response function, and the B-force would perform aggressive preventive patrol. Whether performed by a special patrol force or not, the purpose of preventive patrol is to deter crime and to apprehend offenders in the act. To be most effective patrols should be located in the areas where crime is likely to occur at the time it is likely to occur. That is, a desirable distribution of patrol foce during the 1st watch may be a poor distribution during the 2nd watch. Good distribution of the force is the first consideration in maximizing patrol effectiveness. The second consideration is the tactics that should be employed while on patrol. Tactics include the frequency of patrol on specific streets and alleys, frequency of street stops, and location and frequency of premise checks.

The characteristics of burglary and auto theft in District 20 were studied to improve patrol allocation and tactics against these crimes. The study dealt with the general crime problems of burglary and auto theft. It did not deal with allocation of men and tactics against specific crime patterns. The continual review of cases on a day-to-day basis is necessary to detect crime patterns and to deploy against these patterns.

District 20 is approximately three miles east to west and four miles north to south. It is located on the lake at the far north end of Chicago. The northern boundary of the district is Evanston.

The neighborhoods included in the district are Edgewater and Rogers Park in the northeast, West Rogers Park in the northwest, Lincoln Square in the southwest, and Uptown in the southeast. District 20 is very heterogeneous in its socio-economic characteristics. Its inhabitants include transient workers in the urban renewal area of Uptown as well as executives living in single family dwellings in West Rogers Park.

Uptown is the southeast corner of the district. It is characterized by the highest crime rate within the district. It has a concentration of Puerto Ricans, Indians and Appalachian Whites. The dwelling units are almost exclusively two and three-story apartment buildings.

Edgewater and Rogers Park, in the northeastern portion of the district, and Lincoln Square, in the southwest, contain primarily two and three-story apartment buildings with some single-family dwellings having a median value of $19,300 (1969). High-rise apartment buildings are located in Edgewater and Rogers Park, along the lakefront on Sheridan Road.

West Rogers Park, in the northwest part of the district, is a middle class neighborhood with a median income of $9,000 (1960). The dwelling units are predominately single family residences with a median value of $24,300.

The sources of information for the study included:

Land use maps for the City of Chicago.

May 1, 1969 beat map for District 20.

Data from CPD period tapes for all burglaries and auto thefts occurring in District 20 from period 8, 1968 to period 7, 1969 inclusive.

All case reports for cleared and on-view cases from period 8, 1968 to period 7, 1969 inclusive.

All burglary and auto theft case reports for April, May and June, 1969.

Numerous discussions with members of the police department.

A study of the tabulated index crimes for each of the 21 districts in the city of Chicago was conducted to gain insight into the general nature of crime in the city and to aid in the selection of a district similar to District 20 to act as a control district in an experiment.

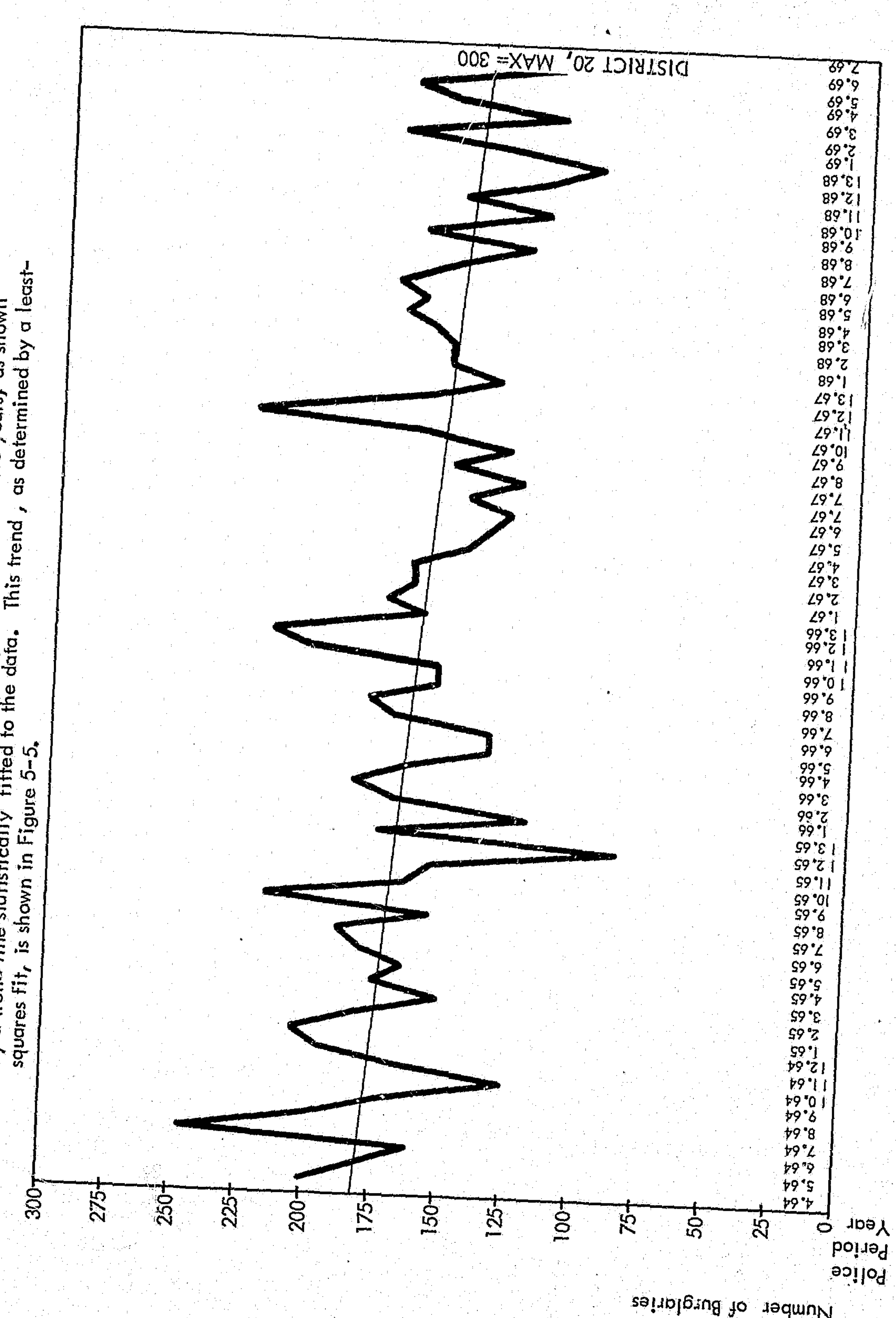
The Chicago Police Annual Report 1967 yielded yearly totals by district for each index crime, and the Police Period Crime Summary Reports were used for period totals and weather data for burglary, auto theft and theft over $50. A later study of more detailed data on District 20 confirmed that these totals are uncorrected statistics. For example, the number of burglaries reported is the sum of new reports of burglary and other crimes now reclassified as burglary, less the number of burglaries now reclassified as other crimes or unfounded. Therefore, if one is interested in the number of *bona fide* incidents in a period, the police period statistics must be adjusted. The crime levels observed were influenced by changes in some district boundaries in 1968 and, more importantly, by unusual events, such as the Martin Luther King, Jr. assassination or the riots in the summer of 1966. Use of the data in a statistical analysis must take unusual events such as these into account. An additional reservation in using these statistics to estimate the level of crime is necessary since as much as one-third of some index crimes are unreported.[8]

The yearly statistics showed that a district with a high incidence per 1,000 residents of one index crime usually has a high incidence per 1,000 residents of other index crimes. The only exception is theft over $50, which is more independent of the other crimes. The high correlation of index crimes supports the widely held belief that crime rates are dependent on the socio-economic conditions of a neighborhood.

Another conclusion supported by the high correlation of index crimes is that offenders generally do not travel long distances to commit crimes. If offenders traveled outside of their districts to commit crimes, we would expect a district high in one crime category to be low in another.

The period statistics were examined for long term and yearly periodic trends. In addition, the correlation by period of the various districts with each other was studied.

The city statistics are dominated by a few high crime districts. While the city shows an increase in burglary from 1965 to 1969, this increase is accounted for by only five districts. Half the districts show a decline and District 20 shows the greatest decline. (See Figure 5-5) Auto theft and theft over $50 show an increase over the city but for these crimes the change is more uniform from district to district. Burglary is not seasonal, while auto theft and theft over $50 are quite seasonal, reaching a peak in the summer.



Incidence of Burglary in District 20

Figure 5-5: In calendar year 1968, there were 1,964 burglaries in District 20. This is 6.8 burglaries per 1,000 persons as compared to the city average of 9.8 burglaries per 1,000 persons. Burglary has been declining over the last five years, as shown by a trend line statistically fitted to the data. This trend, as determined by a least-squares fit, is shown in Figure 5-5.

With respect to burglary, District 19 (to the immediate south of District 20) seemed most like District 20 in that, if the level of burglary in one is high, the level in the other tends to be high also. However the correspondence was not strong enough to use District 19 as a control district.

In the year studied (period 8, 1968, to period 7, 1969), there were 1,858 burglaries. On the case reports each burglary is classified by type of premise. All burglaries were placed into one of three groups:

1,140 Residential or residential garage.
592 Commercial.
126 Miscellaneous (including schools, churches, officers, and warehouses).

1,858

Residential and commercial burglaries were studied separately because their characteristics differ, and the use of patrol against the two should be different.

The offenders in burglary incidents can be placed in three general categories: dope addicts, youths, and professionals. The severity of a residential burglary is probably greater than that of a commercial burglary. However, commercial burglary seems more amenable to patrol than does residential. In terms of economic loss, the average loss in a residential incident was $461, while the average loss in a commercial incident was $343. Moreover, the personal loss in a residential burglary is usually greater than the economic loss because many items that are stolen are irreplaceable because of their personal and sentimental nature. The psychological effect on the victim is also greater in residential incidents. Having one's home invaded probably causes more anxiety and makes a more lasting impression than having a business burglarized.

Patrol against commercial burglaries is easier because there are about 35 miles of commercial property with 592 burglaries, or about 17 commercial incidents per linear mile per year, while there are about 150 linear miles of residential property with only 7½ residential incidents per linear mile per year. Therefore, the opportunity for a patrol car to detect a residential burglary in the same distance traveled is less because the burglary density per linear mile is less. Moreover, many residential burglaries occur above the ground level, with no signs of the burglary visible from the street. On the other hand, most commercial burglaries occur at ground level with signs of forced entry making them more detectable by a police patrol.

Assuming that during the year the police did not abandon residential patrol, they were far more effective in making detections of commercial burglaries than residential. The police detected 17 burglaries during routine patrol. All 17 of these were commercial incidents even though there were twice as many residential burglaries as commercial burglaries.

Commercial burglary seems to be amenable to patrol activity because signs of the burglary are frequently visible to patrol vehicles. To increase the effectiveness of patrol against commercial burglary, patrol units should be located where the crime is most likely to occur. The precise effect of increased patrol on the level of crime is unknown and could be the object of experimentation. However, it seems reasonable to assume that increased patrol will deter crime. This is supported by the observation in District 20 that the incidence of crime in a four-block radius surrounding the District 20 headquarters is among the lowest in the district.

Patrol against commercial burglary is primarily the responsibility of the 1st and 3rd watches. The breakdown is time of day of the 592 commercial burglaries studied is:

337 Night
43 Day
212 Unknown

Increased patrol will also increase the chance of detecting a burglary in progress. In the year studied there were 17 patrol detections of commercial burglaries. Eight of these were detections of burglaries in progress of which six resulted in an immediate arrest. It is difficult to determine the exact time of a commercial burglary because only about 3 percent of commercial burglaries are detected in progress. In most cases, the burglary is detected by the owner or an employee upon opening the establishment in the morning.

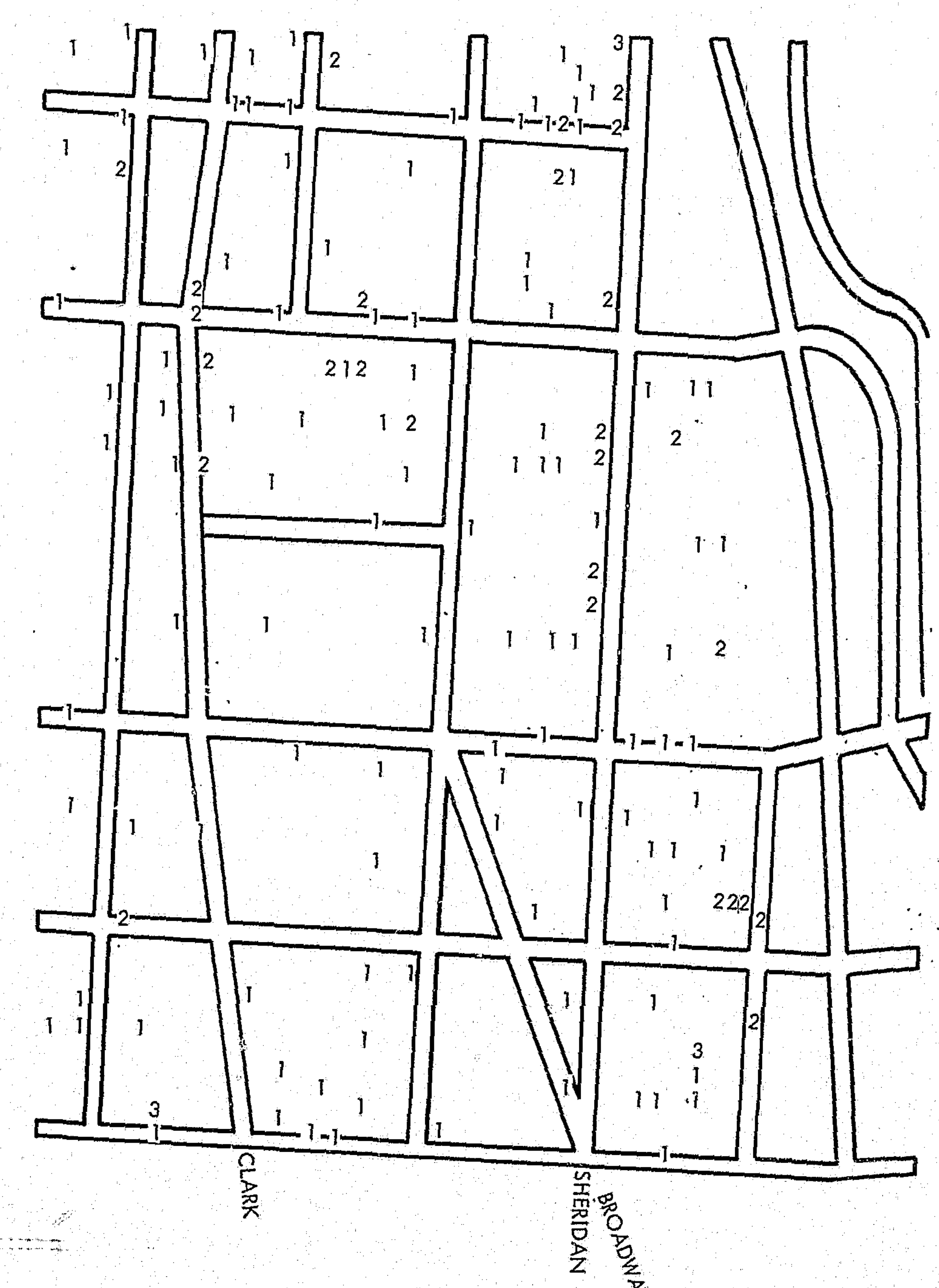
The definition used here for a patrol detection is that a unit detected an unreported burglary while on routine patrol.

Figure 5-6 shows the southeast part of a plot of day residential burglaries. The plot of commercial incidents showed a concentration of burglaries on Devon, Broadway and Lawrence west of Ravenswood. Burglary incidence was concentrated on these streets even though heavy concentrations of commercial property also exist on Lincoln, Western, Clark and Howard. (The complete set of plots generated in this study were given to the Chicago Police Department as a supplement to this report.)

The risk of burglary varies significantly by premise

Figure 5-6: Computer Plot Showing Location and Number of Daylight, Residential Burglaries.

To determine the streets which experienced unusual concentrations of commercial burglaries, a program was developed to plot the location of crime in District 20. Available on the period tapes of the CPD is the location of each incident. The location is specified by a N-S coordinate and E-W coordinate. Each City block was divided into sixths and the number of incidents in each sixth of a block was plotted. A transparent overlay showing the main streets and street names was used with the plot.



type. The number of burglaries of each premise type was divided by the total number of these premises in District 20, as shown in the yellow pages, yielding the following:

Table 5–6
Chance of Premise Being Burglarized

Establishment	Percent
Tavern or liquor store	26
Restaurant	23
Gas station	22
Laundromat	17
Supermarket	15
Cleaning store	12
Church	16

Therefore, on the average, 26 per cent of the taverns and liquor stores in District 20 are burglarized every year. This suggests that patrolmen check taverns, liquor stores, restaurants and gas stations.

Another tactic which could be used to reduce commercial burglaries is more active patrol of alleys behind commercial property between the hours of 1800 and 0600. Table 5-7 shows the point of entry and exit in the 146 commercial burglary incidents in April, May and June, 1969.

Assume the detectability of a rear entrance is the same as a front entrance. Approximately the same number of entrances are made in the rear as in the front and almost twice as many exits are made in the rear. Therefore, there is a greater chance of detecting burglaries after commission by patrol in the rear and an equal chance of detecting a burglary in progress through patrol in the rear. However, of the

Table 5–7
Entries and Exits for Commercial Burglaries

Point of entry	Percent	Point of exit	Percent
Rear door	24	Rear door	36
Rear window	8	Rear window	5
Front door	23	Front door	19
Front window	6	Front window	3
Side door	4	Side door	4
Side window	6	Side window	3
Roof or skylight	5	Roof or skylight	3
Basement	3	Basement	3
Other	7	Other	6
Unknown	9	Unknown	11
Does not apply	5	Does not apply	7
Total	100	Total	100

17 commercial incidents detected by patrol, 11 were detected in the front and only three were detected in the rear. In the remaining three cases, the point of detection couldn't be determined from the narrative. This indicates that, at present, patrol is heavier in front.

After an examination of commercial property in District 20, the assumption that detection can be made as readily in the rear as the front seems reasonable. In general, the lighting is not as good on the alley side of commercial property as on the street side. However, commercial buildings abut on the alley or have a parking and loading area in the rear. Auto headlights or a spotlight afford good visibility of rear doors and windows. Usually a vehicle can drive very close to the doors and windows for added visibility.

Since more exits occur in the rear than the front, suspicious persons or vehicles are more likely detected in the rear than the front.

There are specific signs of burglary the experienced police officer seeks; broken glass, open doors or windows, unusual sounds; lights on when they are usually off, or lights off when they are usually on. These are obvious clues. In checking a premise from his vehicle or on foot, the officer can spotlight door locks and window ledges to detect pulled locks or pry marks.

Residential Burglary

70 percent of the residential burglaries occurred in apartments and 30 percent occurred in single family dwellings. The times of occurrence of the 1,140 residential burglaries were:

641 Day
263 Night
236 Unknown

The daylight burglaries occur in both apartments and single family dwellings. Night time burglaries concentrated in single family dwellings. The shift in location of day and night residential burglaries can be seen in our plots of day residential burglaries (partly shown in Figure 5-6). The high incidence of day burglaries between Sheridan Road and Broadway contrasts with a low incidence of night burglaries in this area. In the same plot for the entire district, an increase in the incidence of night burglaries can be seen in the single family dwelling units in the northwest part of the district.

The point of entry, point of exit, and location of victim at the time of burglary is shown for residential burglaries in Table 5-8.

In buildings with four floors or less, 47 percent of the burglaries occurred on the first floor while only 31 per cent occurred on the second floor. Since there are approximately the same number of second floor apartments as first floor apartments, the risk of burglary is 50 percent greater on the first floor than the second.

Twenty-one percent of the burglaries in apartments of four floors or less occurred on the third floor. However, it cannot be concluded from this that burglary is less likely on the third floor apartments as second floor apartments.

In high rises (buildings with at least five floors), the data indicates that burglary is less likely at higher floors. The percentage of burglaries at each floor is shown in Table 5-9.

The percentage of first floor burglaries may be low because many high rises have no first floor apartments. Again this data indicates lower risk at higher floors, but the exact risk depends on the number of apartments at each floor. This number is unknown at this time.

The effectiveness of patrol against residential burglary is probably much less than against commercial burglary. It is impossible, of course, to measure the deterrent effect of residential patrol. The

Table 5–8
Location of Entries, Exits and Victims for Residential Burglaries

Point of entry	Percent	Point of exit	Percent
Front door	35	Front door	38
Front window	7	Rear door	30
Rear door	25	Basement	6
Rear window	4	Side door or window	4
Side door or window	7	Other	15
Basement	6	Unknown	7
Other	9	Total	100
Unknown	7		
Total	100		

Location of victim at time of the crime	Percent
Work	39
Visiting	16
Out of house (miscellaneous)	14
At home	13
Shopping	11
Out of town	7
Total	100

Table 5–9
Burglaries in High-Rise Apartments by Floor

Floor	Percent
1	12
2	23
3	24
4	13
5	12
6	3
7	0
8	3
9	3
10	3
11 or higher	4
Total	100

likelihood of detecting a residential burglary in progress is much less than the likelihood of detecting a commercial burglary. Patrol of alleys behind residential property is not recommended. The visibility is restricted in most cases. The distance residential buildings are located from the alley limits visibility, and usually garages or shrubbery obstruct the line of sight.

AUTO THEFT IN CHICAGO

The number of incidents of auto theft is almost as high as for burglary. In the year studied there were 1,602 incidents of auto theft in District 20. There are two general categories of auto thieves, joyriding teenagers and professionals. Ninety-three percent of the stolen autos in the city in 1968 were recovered. Since professionals usually cannibalize the autos or dispose of them out of state, it is reasonable to assume that most recovered autos were stolen by joyriders.

According to the auto theft section of the detective division, approximately 40 percent of all autos stolen were stolen with the key left in the ignition. In District 20, the following was found regarding the 1,602 incidents of auto theft in the year studied.

420 With key in ignition.
53 Without key.
1,129 Unknown.

Therefore at least 25 percent of the autos stolen were stolen with the key left in the ignition.

It is suggested that Regulation 27-268 of the Municipal Code of Chicago be enforced. This law requires that the key be removed from the ignition of an unattended motor vehicle. It is believed that enforcement by traffic officers on three-wheeled motorcycles would be easy.

Consideration should also be given to empowering meter maids to enforce this law. It seems that people would be more likely to leave the key in the ignition on a commercial street where the car will be unattended for 5 to 60 minutes than on a residential street. Therefore meter maids would be especially effective in enforcement. In response to a request, a survey was taken by meter maids throughout the City. In the areas they normally work, they counted the number of vehicles in a block and counted the number with keys in the ignition. Of 4,352 vehicles checked, 3½ percent were unattended with the key in the ignition.

There is evidence that the steering column locks have reduced theft of autos. With steering column locks joyriding should be deterred. However, these locks will be ineffective if individuals continue to leave the key in the ignition of the car.

The greatest opportunity for apprehending an auto thief exists in the hours immediately after the theft and, frequently, before the vehicle has been reported stolen. To aid in this apprehension process, consideration should be given to a direct access terminal to the computerized auto registration file in Springfield, Illinois. In this way the owner of a vehicle could be determined in minutes. At present, it may take several hours to check an auto registration.

Rapid access to auto registrations encourages officers to use the file in street stops or at the time of issuing a traffic citation. This terminal would also avoid the delay in acquiring new registrations at the beginning of each year, since the registration would be available to the police department as soon as they were issued in Springfield. The cost and benefits of a direct access terminal or some other system of rapid retrieval has not been carefully studied but it is suggested for further consideration by the CPD.

In District 20 the areas of highest incidence of auto theft were along the southern portion of the district south of Foster and along the corridor between Sheridan Road and Broadway from Foster north to Devon. (Plots of the location of auto thefts and auto thefts with the key in the ignition were presented as a supplement to this report.)

Proposed Experiments

Four experiments are proposed to test the conclusions of our study and to study the effect of patrol of the level of crime.

Experiment 1: Patrol units should be specifically assigned to cover the areas with a high incidence of commercial burglary. These might be special cars or the regular beat car. This activity should take place between 1800 and 0600 on weekdays and on weekends. Patrol activity should be split between front and rear and activity reports should be maintained. The effect of patrol on the incidence of commercial burglary in these areas should be studied and the relative value of front and rear patrol should also be studied. If the intensity of patrol was increased only in certain areas of District 20, the degree to which commercial burglary is displaced to other areas with less patrol activity should be observed.

Experiment 2: All patrol units should intensify patrol against commercial burglary. The patrol should include both front and rear patrol. The crime plots should be used to make the officers aware of the areas where commercial burglary is most likely to occur. Activity reports should be kept to aid in the evaluation of the patrol.

Experiment 3: Patrol should be intensified in the corridor between Sheridan Road and Broadway from Foster to Devon. The officers should be made aware of the crime problems in this area and the effect of the intensified patrol should be evaluated.

Experiment 4: An experiment using a split patrol force, similar to the experiment performed in District 14, should be conducted using the knowledge of crime location and tactics developed in this study.

Measures of Effectiveness

Intuitively, the ultimate measure of effectiveness of police work is the number of crimes committed. Unfortunately, the number of reported crimes is highly variable from period to period, and thus the effect of a change in police tactics may not be apparent. Several methods exist to increase the visibility of a change in crime level.

First, a time series analysis can be conducted to detect long term and seasonal trends. Figure 5-5 showed the number of tabulated burglaries in the 20th District from the 4th period of 1964 to the 7th period of 1969. The scale runs from 0 to 300 burglaries. The long term decrease in crime level can be readily seen, while there are fluctuations but no seasonal trend. That is, the average number of burglaries in the summer is about the same as in the winter. There is no indication that a decrease in crime level from one period to the next or from a similar period of the previous year is an indication of greater police effectiveness rather than just a random fluctuation.

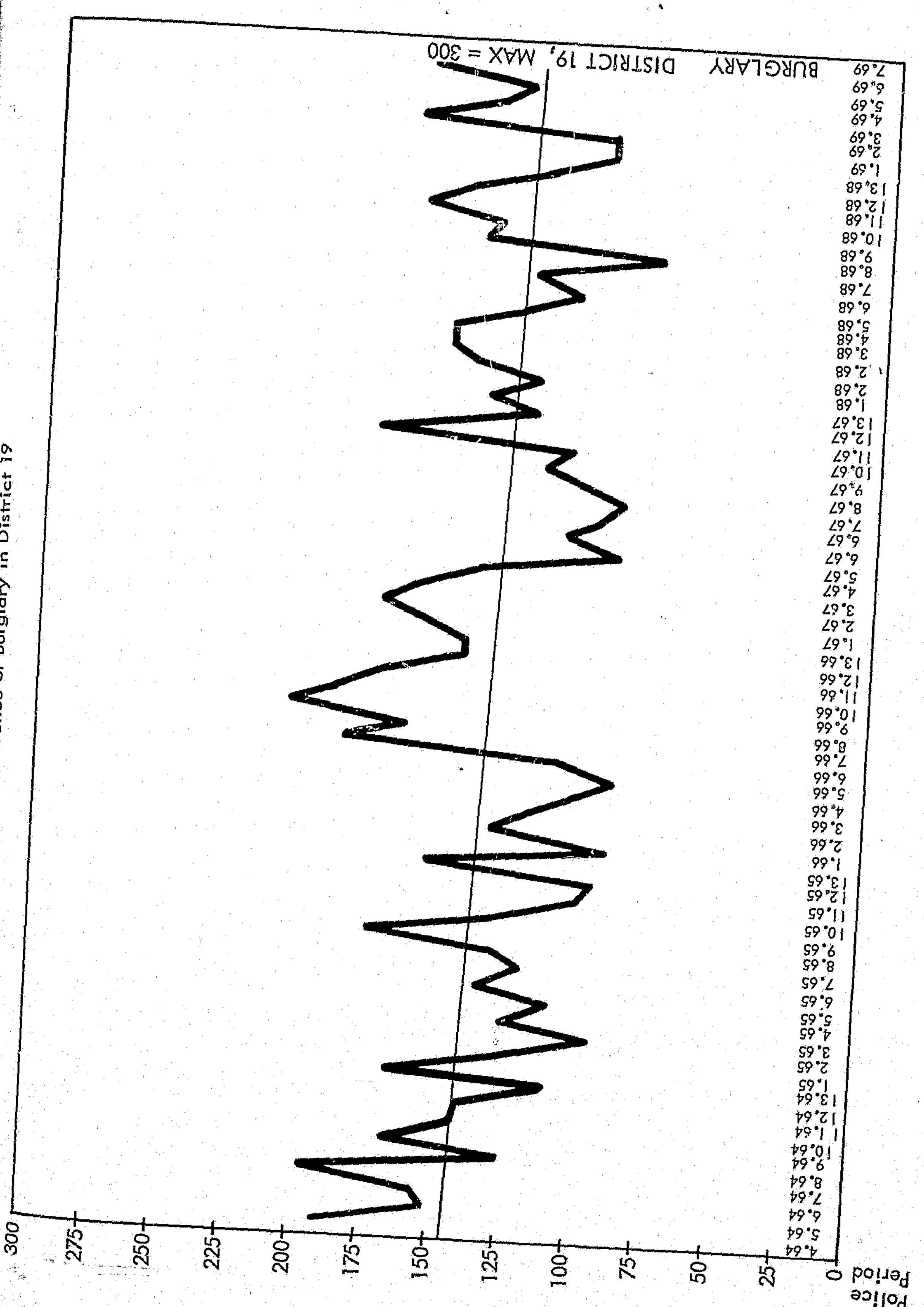


Figure 5-7 : Incidence of Burglary in District 19

A second method of analysis is to designate a district that is similar in the numbers of crimes each period as a control district. While the Town Hall (19th District) is most similar to the 20th in that there is the same long term downward trend and the peaks and valley tend to be similar (See Figure 5-7), there is still much difference between the two.

A more detailed description of the crime level would have to make assumptions about the nature of crime and take other data into consideration. This approach may be made necessary by the fact that periods of high crime levels tend to be followed by similar periods and likewise for periods of low crime levels. Unusual events, such as riots, and the fact that the data are obtained by subtracing reclassifications as well as counting incidents, would both tend to create high levels of crime followed by low levels and vice versa. The observable tendency of crime levels to persist renders the normal statistical procedures invalid and indicates that some undefined process is at work.

Other measures of patrol effectiveness are the ratio of detections of crimes by the police to the number of reported crimes or the ratio of crimes cleared by arrest to the number of reported crimes. Since police patrol has two functions, detection and deterence, these measures of effectiveness measure only part of the patrol function, namely detection. They have the advantage of not being rendered invalid if the reported crime increases due to better police work.

Improvement in the CPD

A direct access auto registration file should be maintained comparable to the present HOT file. Rapid availability of auto registrations would aid in apprehending auto theives through street stops. Officers would be encouraged to routinely check registrations when issuing a traffic citation. A terminal with direct access to the auto registration file in Springfield should be considered. This would obviate the delay in the CPD obtaining new registrations from Springfield.

A random access stolen property file should be considered. This file would aid detectives in checking property believed to be stolen. By keying into the system a description or serial number of the property, the file would be checked for stolen property matching the description or bearing the designated serial number.

Plots of the location of crime similar to Figure 5-6 could be generated by computers for any district or beat, for any crime or combination of crimes and for any time period. It is believed that these would aid in understanding the crime problem of a district. The commander or tactical unit could allocate men more effectively.

The cost and benefits of an expanded Management Information System should be considered by the CPD.

Consideration also should be given to using secretaries and clerks to perform many of the tasks now performed by police officers. Many times, these highly trained and highly paid police officers perform tasks which could be done equally well or better by lower-paid personnel. Utilization of the investigative skills of a detective would be increased if a secretary typed his case reports. To save the time of writing, a dictaphone might be made available or a portable recording device used at the scene of an investigation to make notes that would become the supplementary report. Portable recorders are relatively inexpensive, costing less than $100.

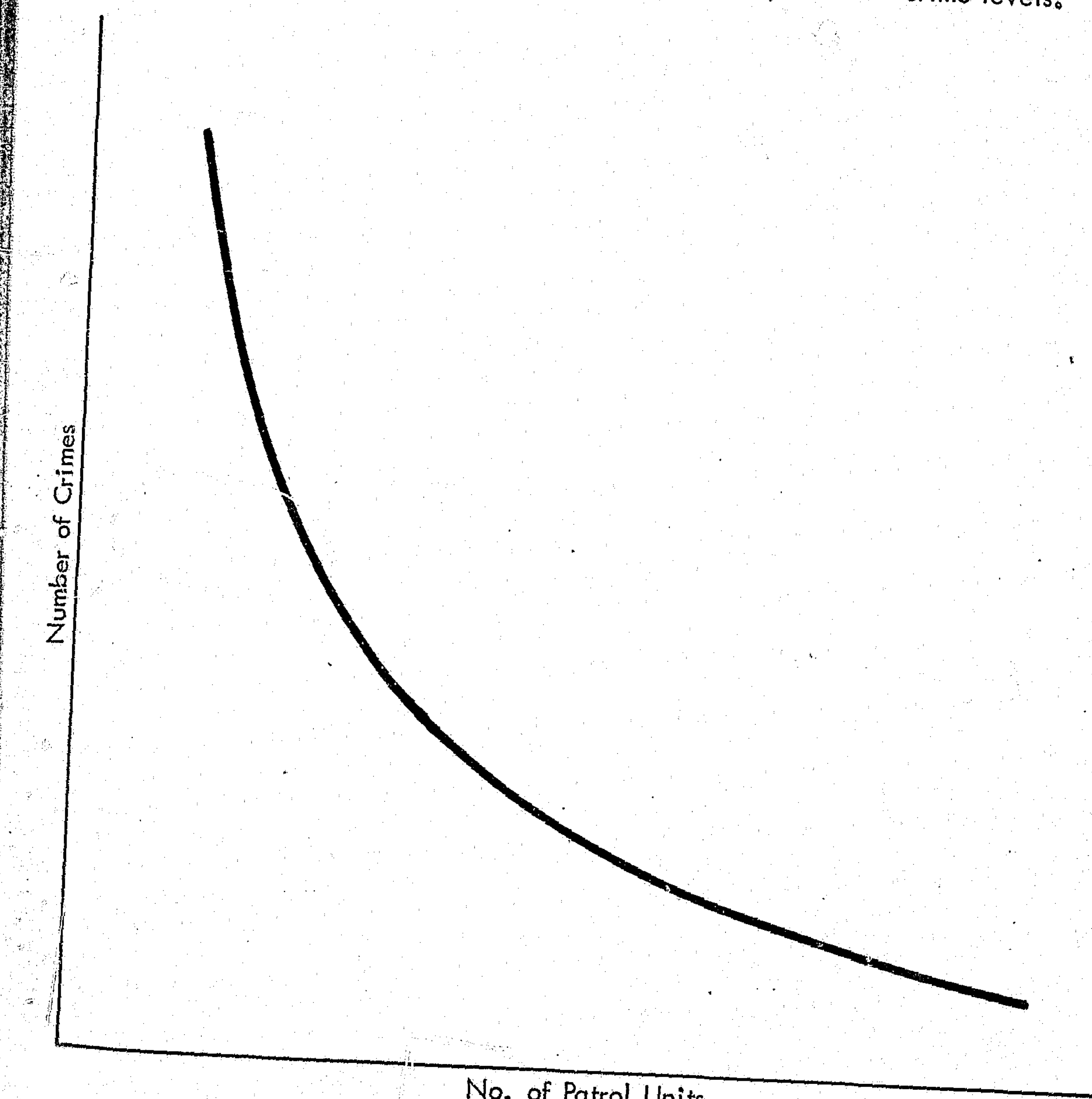
Use of forecasting models to predict calls for service and incidence of crime should improve the allocation of the patrol force and the general effectiveness of the CPD. These forecasts should be made, at least, for each eight-hour watch. An area may have a relatively high incidence of crime on one watch and a relatively low incidence on another. This was noted in the incidence of residential burglaries. The separate forecasting of calls for service and crime incidence is particularly useful with a split force for response and prevention.

The forecasts should be broken down further by type of call. Knowing the average time required to to service each type of call enables one to determine fairly accurately the workload in an area. The workload then determines the number of men required in the response force. The area of forecast might be the area of command of one segeant. The sergeant would then disperse the men within the area, depending on the type of preventive patrol needed.

Models of the effect of patrol activity on crime might be studied by mathematical techniques and experimentation. It is important to know the effect of patrol activity on crime levels so that the preventive patrol can be allocated most effectively. One such mathematical model is discussed in the following technical section. This type of functional relationship between intensity of patrol and crime levels is represented by the graph in Figure 5-8.

Another possible relationship is depicted by the next graph. In this model, crime again decreases as the number of patrol units increases, but the marginal effectiveness of each unit increases to a point (A) before the marginal effectiveness begins to decrease in Figure 5-9.

Figure 5-8: First hypothetical relationship between patrol and crime levels.

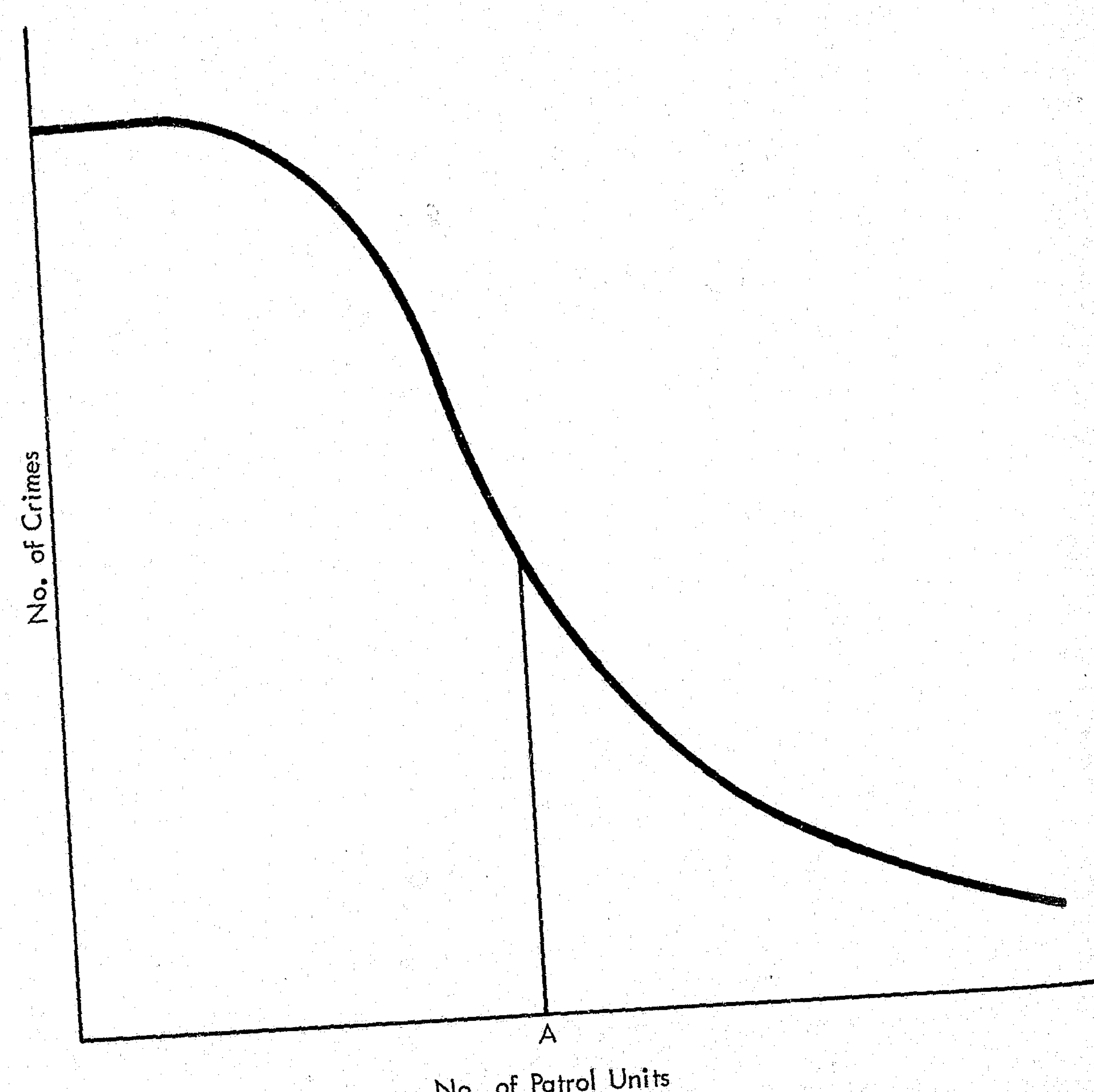


ROBBERY IN THE SECOND DISTRICT

The Second Police District has experienced a very high incidence of both armed and strong-armed robberies for the past several years. The frequency of robberies is such that the Second District accounts for about one and one-half times the number occurring in the next highest district in the city. This chronic situation prompted the chief of the Patrol Division to request the Operations Research Task Force to lend whatever assistance possible toward reducing the magnitude of the robbery problem. The invitation was readily accepted, not only to combat the specific problem of robbery in the Second District but also because of the potential of generalizing any promising results to the reduction of all street crime occurring anywhere within a large urban center.

The Second District is the most densely populated

Figure 5- 9 : Second Hypothetical Relationship between Patrol and Crime Levels.

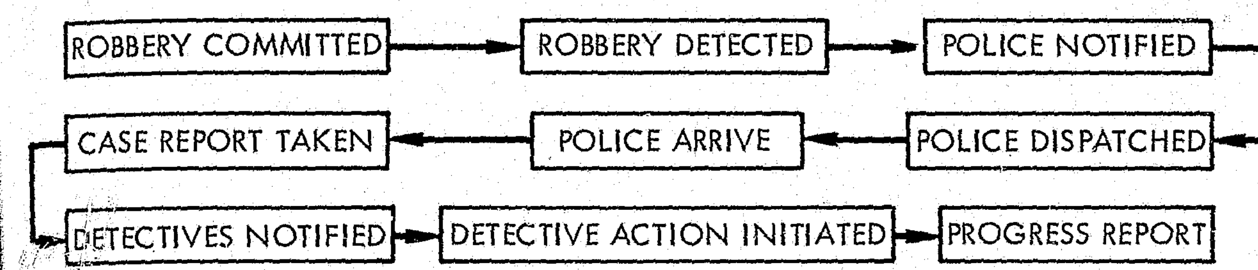


district in Chicago, with 154,831 people living in 4.313 square miles, according to the 1967 Annual Report of the Department. This is an average of 38,217 people per square miles as compared to the City-wide average of 15,318 per square mile. Of the twenty-one police districts in the city, the Second ranks fourteenth in population and nineteenth in area. Thus, the Second District accounts for only 4.45% of the City's population and 1.9% of the City's area but contributes 8.6% of the city's index crimes and 13.9% of the city's total robberies. In 1967 there were 2,553 robberies in the Second District while the Third District ranked second in robberies, accounting for 1,696.

Initial analysis by ORTF was to survey the techniques for preventing robberies and/or apprehending offenders. Particular attention was attached to an understanding of Reactive Force and Preventive Force procedures in the Second District.

There are 506 police officers assigned to the Second District including the district commander, three watch commanders (captains), six lieutenants, 32

Figure 5-10 : Police Response Flow Diagram



sergeants, and 464 patrolmen. These figures include all officers, vice detectives, tactical unit personel and detail personnel. This number is higher than that of any other district in the city. For comparison, the second largest city police department in Illinois, Peoria, has 188 police officers.

A better understanding of the deployment of police within the Second District may be had from studying the work shifts. At 2300 hours, one-half of the first watch patrol complement reports for roll call followed at 2400 hours by the remaining half. The second and third watches report at 0700, 0800 and 1500, 1600 hours respectively. Second and third watch power shifts report at 1000 hours and 1800 hours respectively. Power shifts are patrol complements which allow assignment of beat cars to every one of the district's thirty motorized beats. In addition, there are three umbrella (single street) beats, five squadrols, five sergeants, two vice cars, and one field lieutenant assigned to all three watches.

The Second District employs two tactical teams, one reporting at 1000 hours and the other at 1800 hours for exclusive preventive patrol. The special employment teams are utilized from 1700 to 0100 hours in the second district. The First Area Task Force preventive patrol personnel are often assigned within the boundaries of the second district because of the high crime rate.* Thus, there may be five district teams, plus the Task Force, patrolling the Second District during the third watch.

A nine-block flow diagram depicts the relationship of significant time events of police response following a robbery. (Figure 5-10).

In most instances of robbery, the victim himself serves as the detection device, except in those cases where he is unable to notify anyone. If he or some other person is unable to notify the police directly, a considerable delay could result. Otherwise the time of detection can be considered synonomous with the commission of the robbery.

Assuming the police do not witness the robbery, a finite interval will elapse before they are notified. The notifications may be effected by telephone or by hailing a passing police car.

The telephone call from the victim is switched automatically to the appropriate zone operator who dispatches the nearest available beat car to the scene.

Depending upon the distance to be traveled and existing traffic conditions, a variable time internal will elapse before the police actually arrive at the robbery scene or the physical location of the victim.

The investigating officer will interview the victim and complete a Robbery Case Report. If a reasonably detailed description of the offender(s) can be obtained and a relatively short time has elapsed, a "Flash" message may be sent over the police radio network. Depending upon these and other characteristics of the robbery, hot search procedures may be initiated. In the Second District it has been the practice to reconnoiter the immediate vicinity with the victim to see if the offender(s) can be observed.

At some point in time following the arrival of the beat car, the detective division will be notified of the robbery and its details.

Detective action is formally initiated following notification by the patrol division police officer. Usually an interview with the victim and any witnesses will be made by the assigned detective. A suspense date is assigned for completion of the detective investigation.

After the prescribed period for investigation has elapsed (usually seven days), the detective must submit the results of his investigation in the form of a supplementary report which recommends that the case be closed or request additional time for continuing the investigation.

If at any point in the investigation an arrest or other type of clearance is made, the sequence is terminated except for court appearance.

*The First Area includes Districts 2, 21 and 1.

Methodology of the ORTF

The initial effort was directed toward describing the robbery problem in greater detail so that effort could then be specifically directed toward the more promising areas of endeavor. Not only did this approach prove effective in identifying the promising areas, but also the detailed, unequivocal description of the characteristics of these crimes proved useful in itself. These descriptive statistics helped dispell what could be called the "myths" concerning the nature of the robbery problem. For instance, it was a common belief among the police officers that the overwhelming majority of the robberies occurred in locations not amenable to street patrol. The detailed statistics indicated that approximately 65 percent of the robberies actually took place on the open street.

The specific data elements which were identified as pertinent to the robbery study are enumerated below:

A. Record document number.
B. Street address and rectilinear coordinates of place of occurrence.
C. Beat of occurrence.
D. Day of week.
E. Date.
F. Time.
G. Time Police Communications Center was notified.
H. Time beat car was dispatched.
I. Time beat car arrived to interview victim(s) and witness(es).
J. Time Detective Division was notified.
K. Time assigned.
L. Dollar value of the articles (or cash) taken from the victim(s).
M. Number of offender(s) participating in each robbery and victim(s).
N. Race(s) or offender(s) and victim(s).
O. Sex(es) of offender(s) and victim(s).
P. Estimates age(s) of offender(s) and victim(s).
Q. Number arrested.
R. If arrest(s) were made, the branch of the Department which the arrest; for example, beat car, task force, detective.
S. Type of arrest; for example, on view, result of flash message.
T. Arrest delay time from occurrence.
U. Location of the robbery, whether street, vehicle, business, or residence.
V. Armed or strong-armed.

W. If armed robbery, type of weapon employed.
X. If arrest was not made, type of escape; such as foot, private vehicle, taxi.
Y. Whether or not the victim(s) required medical treatment.
Z. Whether or not the victim(s) had been drinking.
AA. Occupational status of the victim(s).
BB. The type of occupation of the victim(s) if related to the robbery; for instance, newsboy, insurance collector.

Source documents for the above data were the Robbery Case Report, the Supplemental (Detective) Report, and the Record Document card filled out at the Communication Center.

All of the data elements identified in the previous section were punched onto a standard 80-column IBM card. A coding form was prepared to facilitate the recording of data from the source elements.

After keypunching, a reasonably complete data base was available for computerized analysis. The statistical program library at Northwestern University's Vogelback Computing Center was utilized to produce the usual statistical outputs such as means, standard deviations, cross classifications and to conduct multiple discriminant analysis. In addition, graphical output for histograms was obtained.

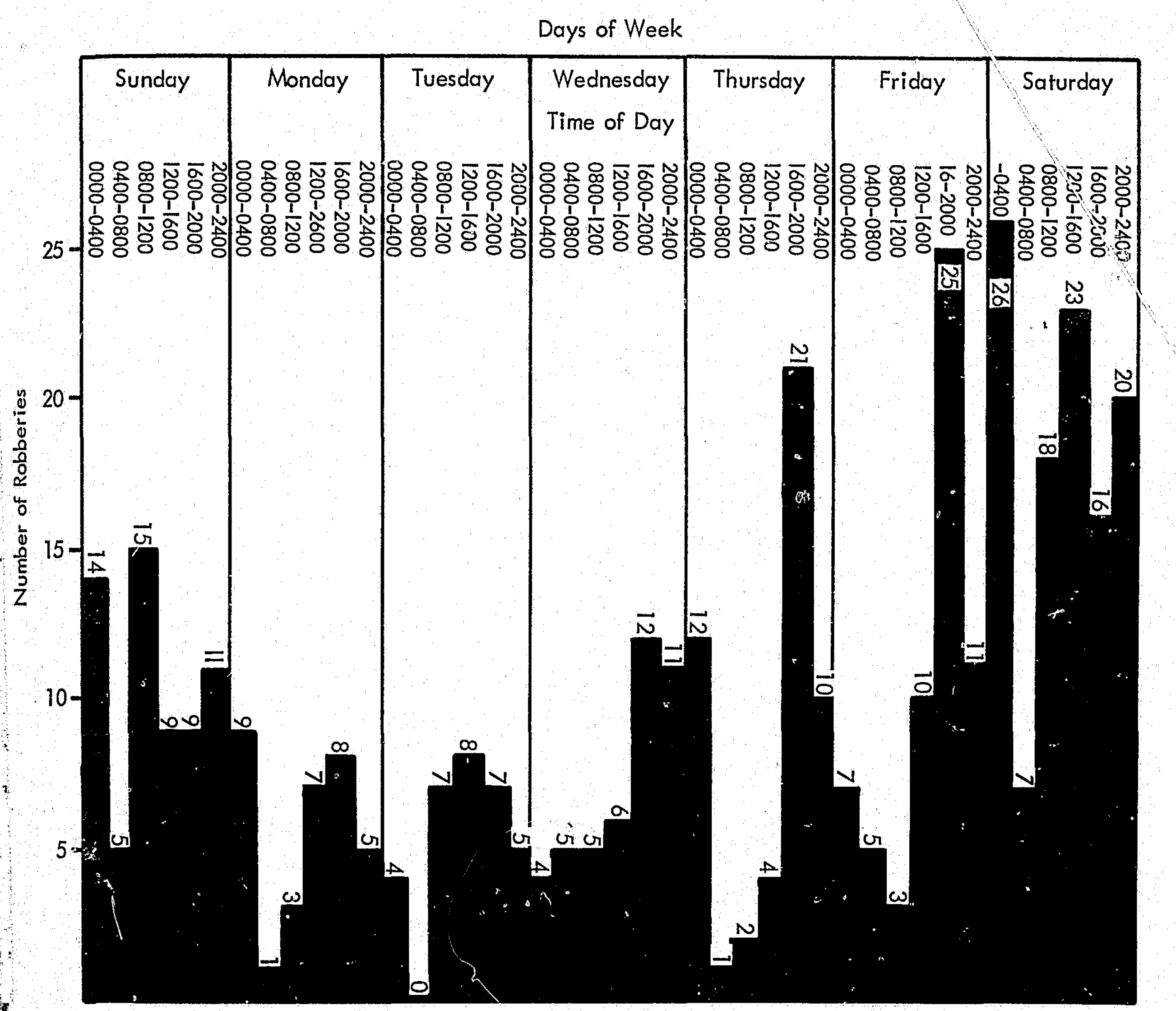
The final sample came to 418 robberies, of which 232 were armed robberies and 175 strong-arm robberies. There were eleven cases in which this armed-strong-arm dichotomy was not entered. In this case, as in all others in the study, the "good" responses were used as a 100% sample.

Saturday showed the highest frequency of robberies, followed by Sunday and Friday; 60% of the robberies were committed on these three days, i.e. from midnight Thursday to midnight Sunday. Tuesdays and Mondays had the least number of robberies: 30 and 34 respectively.

The greatest number of robberies occurred between 7 and 8 p.m., and midnight and 1 a.m. The hours between 6 and 8 a.m. had the lowest frequency of robberies. Only six robberies occurred during these early morning hours.

There were 115 robberies between midnight and 0800 hours, 126 between 0800 hours and 1600 hours and 181 between 1600 and midnight. Sixty-one percent of the robberies on the first watch occurred during the first three hours, from midnight to 0300. After 0300 hours there were few robberies until 1000 hours when they picked up and rose to peak between

Figure 5-11 : Frequency of Robberies by Time of Day and Day of Week
Second Police District–Chicago, February and March 1969



1600 and 2000 hours. The four-hour period 1600 to 2000 hours had a higher frequency than any other four-consecutive-hour period. Over 25% of total number of robberies occurred during these four hours. The frequency of robberies for four-hour periods through the week is shown in Figure 5-11. The first four hours on Saturdays, midnight to 4 a.m. had the greatest frequency (26 robberies).

Geographically, the robberies occurred more toward the west than the east side of the district. Five of the six beats with over twenty robberies were adjacent to State Street. Across State Street all the way from 35th Street to 55th Street is the 27,000 population Robert Taylor Housing Project which may have been a sanctuary for some of the offenders.

Beat 219 with twenty robberies in its five square blocks was particularly dangerous. On the north-south line the robberies clustered toward the center of the district with a high concentration between 43rd Street and 55th Street. Washington Park was the most robbery-free area, having only nine robberies on its two beats. Since this study examined robberies during the cold months of February and March when few people are found in the park, this is not a surprising result.

The picture of robbery in the Second District shows clearly in the map of beats (Figure 5-12) and Table 5-10.

Officers have had the best arrest results on Beat 205 where the most robberies were committed. There

Figure 5-12 : Beat Map of CPD District No. 2

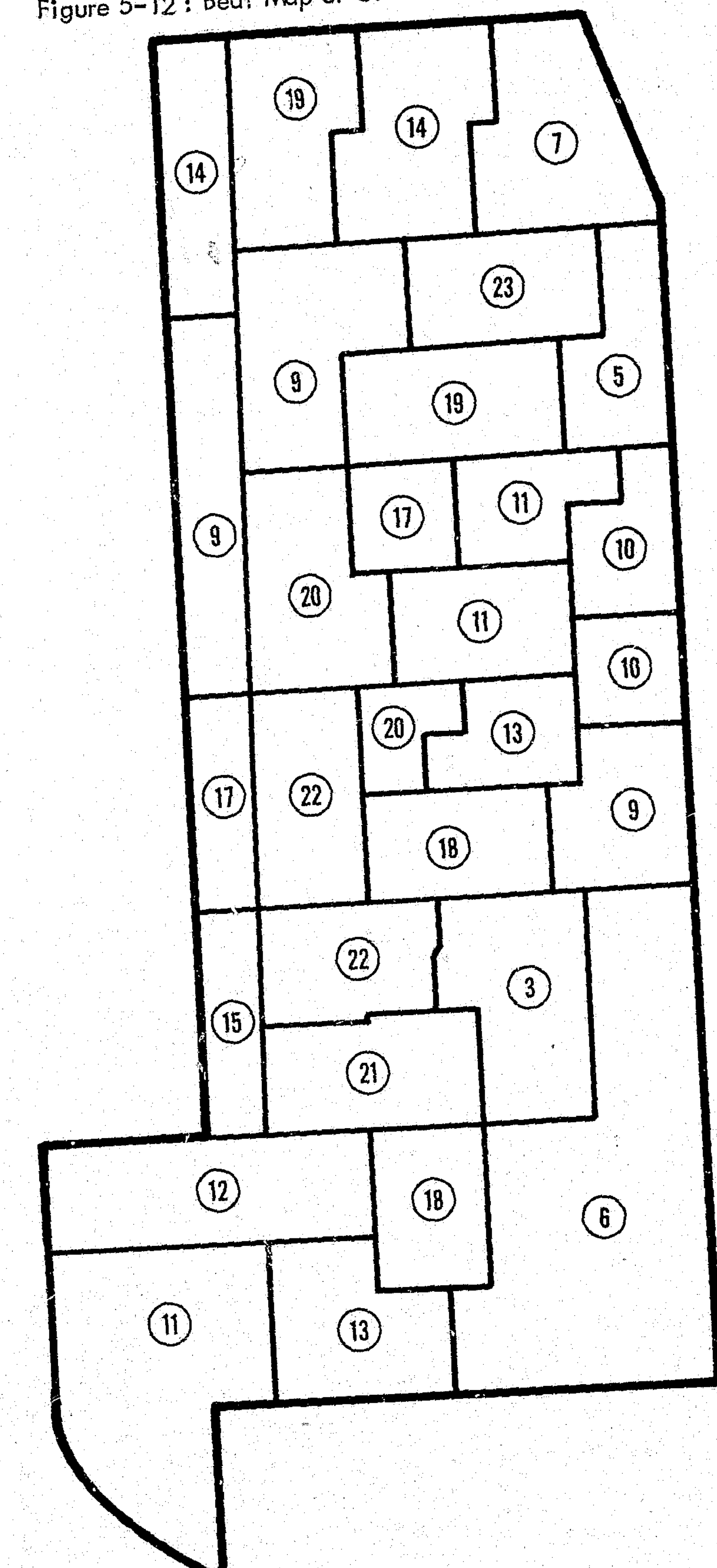


Table 5-10

District 2 Robbery Locations

[See beat map, Fig. 5-13]

Beat	Robberies	Beat	Robberies	Beat	Robberies
201	14	211	11	221	15
202	19	212	17	222	22
203	14	213	11	223	21
204	7	214	10	224	22
205	23	215	10	225	3
206	5	216	13	226	6
207	9	217	18	227	18
208	19	218	9	228	12
209	9	219	20	229	13
210	20	220	17	230	11

were twenty-three robberies on this beat for which ten people were arrested, six by beat officers, one by detectives, and three by citizens.

The losses in these crimes ran from several thousand dollars in one robbery to 25 cents that an older boy took from a student. In a substantial number of the robberies, especially those on Friday night and Saturday morning, there were cash losses of over $100, and in most cases it had been what was left of a weekly or bi-weekly pay. In one case a group of post office employees were having a Friday night party in a third-floor apartment when three men entered armed with a shotgun and revolvers. Six people, all of whom had just been paid, were robbed.

There was not a high percentage of good responses for the category *where robbed*, meaning that type of premises on which the crime occurred. Of the 136 good responses, 65% took place on the street, 14% in residential hallways, and 8% in business establishments. Ninety-two percent of the strong-arm robberies occurred on the street. No strong-arm robberies occurred in any business establishment. All were on the street or in a hallway or in a vehicle.

ROBBERY'S VICTIMS

The Victims

The victim, in 96% of the cases, was a lone victim. This does not mean that he was not in the company of someone but only one person was robbed. In some cases, a store owner was robbed while a customer was in the store, and only one victim was recorded.

Robbery victims were 93% Negro; the reader is reminded that the residents of the district are virtually 100% Negro. Only 27 or the 405 victims were white. These white victims were generally people who went to the district in the course of their employment, i.e. truck drivers, insurance men, etc.

Victims were predominantly male: 83%. The male victims outnumbered the female victims 336 to 67.

The average age of the victims was a little over 34 but the most frequent victims were thirteen (23 victims) and fifteen (22 victims). These were generally newsboys and students who were strong-arm robbery victims of peers. An 88-year-old man was the senior victim and two 8-year-olds the youngest.

There were 390 good responses showing the occupations of the victims. From these it was found that the majority of the crimes were related to the occupation of the victim. That is, the victim, while working, had something of value in his possession, usually cash collected, through his job, and the offender was after it. There were 204 people in this category: 94 local businessmen or their employees, 21 taxi drivers, 9 CTA (Chicago Transit Authority) bus drivers, 9 delivery truck drivers, 5 insurance collectors and 66 newsboys.

Many newsboys, generally between 8 and 15 years of age, do their own paper route collecting in the area. These boys are highly vulnerable. They are usually robbed by one, two or three boys, a few years older than themselves. They are usually approached in a hallway and threatened with a beating by a lone boy or held by one or two boys while another reaches into the newboy's pocket and removes any cash in his possession. In most cases the newsboys do not resist and they are not injured. The losses are from a few cents to several dollars.

Thirteen percent of the victims had been drinking at the time of the offenses. This figure may not show a true picture of the actual offenses: on at least one occasion, several patrons in a tavern, all of whom had been drinking, were robbed. On the other hand, victims who had been drinking may not have answered the question truthfully.

Forty victims, or 10%, were injured to the extent that they required medical attention. Twelve percent of the strong-arm victims were injured as opposed to 8% of the armed robbery victims. Only two women were injured. Eleven percent of male victims needed medical attention and 3% of female victims.

The Offenders

The offenders were all Negro. They had a tendency to offend singly (160 worked alone), in pairs (123 worked with a partner), and in trios; there were 93 groups of three. Only 27 of the robberies were com-

Table 5-11

Armed robberies, District 2 (February and March 1969)

Age	Number of offenders						Total
	1	2	3	4	5	Over 5	
Under 14..........	4	5	4	0	0	0	13
14 to 16..........	7	1	3	1	1	0	13
17 to 19..........	15	17	13	1	1	0	47
20 to 22..........	15	20	13	2	0	1	51
23 to 25..........	18	7	3	1	1	0	30
26 to 28..........	11	9	2	0	0	0	22
29 to 31..........	8	13	0	0	0	1	22
32 to 24..........	6	2	1	0	0	0	9
Over 35..........	15	4	0	0	0	0	19
Total.......	99	78	39	5	3	2	226

mitted by more than three people. This offers no guarantee that large groups will not rob. Two persons found this out the hard way when they left the car at home and took the subway to a south side auto show. When the train stopped at the 22nd Street station, approximately 100 students who had been attending a basketball game boarded the train. The students proceeded to rob everyone on the train before it reached the Indiana Avenue stop. Victims lost their wallets, money, rings, watches, and clothes. The victims felt that a good many attackers got at least part of the loot.

Robbers were almost certain to be male (389 cases) or in mixed company (15 cases). There was the one exception; three 16-year old girls broke the sex barrier with a strong-arm robbery of another girl.

The offenders were in general much younger than the victims, averaging slightly under 22. A great deal of the ages data are, of course, estimates made by the victims. The greatest frequencies come within the ages 14 to 25. There were 67 percent within this age spread. The age 18 had the highest frequency of offenders. There were 31 at this age. The youngest offenders were six and the oldest fifty. (A person who has not attained his 13th birthday cannot be convicted of any offense in Illinois, but the the purpose of this study we are considering any act that would be defined as a robbery not whether the perpetrator is legally of sufficient age to be convicted of a crime.)

The strong-arm robbers were younger as a group than the armed robbers. The strong-arm robbers averaged 19.1 years of age, while those who used a weapon averaged 23.3 years old. Sixty-nine percent of the strong-arm robbers were 19 or under compared to only 32% of the armed robbers. The armed robberies occurring most frequently were perpetrated by 17 to 22 years olds working alone or in groups of two or three. Forty-one percent of the armed robberies were committed by people of this age group and working in these numbers. The highest frequency of strong-arm robbers was in the 14–16 age group. Thirty-one percent were committed by this age group, again by a single youth or groups of two or three (See Tables 5-11 and 5-12).

It has already been shown that 57% of the robberies were armed as opposed to strong-arm. The most frequently used weapon was the revolver, followed by the knife. There were 128 revolvers used, 52 knives, and 6 shotguns.

When the crime was complete, the offender(s) left the scene on foot in 334 cases and in a vehicle in 7 cases. One offender came into a lunch counter armed with a revolver. He leaped over the counter and opened the cash register which to his chagrin was empty. He then told the countergirl that he would return after she had taken in some money, leaped back over the counter, and left on foot. The man had not returned by the termination of the study.

A total of 105 of the 418 crimes were cleared by the arrests of 192 people. There were 59 single offenders arrested, 20 pairs, and 17 trios. A group of four people was arrested on six occasions; five, twice; and there were eight arrested for one crime.

The district patrolmen made 58% of the arrests. The detective division accounted for 24%. Seven percent were made by district tactical units and the area task force accounted for 5%. Four would-be robbers were overcome by their potential victims and held for the police.

Almost half of the arrests (44%) were made within an hour following the offense and another 24% within the first twenty-four hours.

Table 5-12

Strong-Arm Robberies District 2

Age	Number of offenders						Total
	1	2	3	4	5	Over 5	
Under 14..........	9	4	4	1	0	1	19
14 to 16..........	21	14	15	3	0	1	54
17 to 19..........	10	7	8	1	1	4	31
20 to 22..........	2	5	7	0	1	0	15
23 to 25..........	6	3	6	1	0	0	16
26 to 28..........	3	2	4	0	1	0	10
29 to 31..........	3	1	2	0	0	0	6
32 to 24..........	0	0	1	0	0	0	1
Over 35..........	3	3	1	0	0	0	7
Total.......	57	39	48	6	3	6	159

Table 5-13

Comparison of Crime and Arrests in Chicago and Los Angeles

	Los Angeles	Chicago's 2d district
Total crimes.....................	1,905	418
Cleared by arrest................	482	105
Percent cleared by arrest..........	25	25
Percent of arrests made by patrol force....................	91	* 70
Percent of arrests made within 1 hour following the crime.......	† 43	44
Percent of arrests made within 1st week following the crime.....	† 67	86

* This includes district and task force personnel.
† Approximate figures taken from a graph.

The Challenge of Crime in a Free Society documents a study of 1,905 crimes examined in Los Angeles in which 25% were cleared by arrest.[9] This study included all crimes, not just robberies, but there are some similarities which may be shown between that study and this second District robbery study.

Since the Los Angeles study included all crimes, many of the offenders were known to the victims. Of the 482 cleared cases in that study, 63% involved suspects named in the original case report, that is, either offenders known to the victim or offenders arrested at the scene of the crime. In the 2nd District, less than 5% of the robbery offenders were known to the victims: 44% were arrested within hours following the crime. Only 14% of Chicago arrests were made after a week following the crime while one-third of the Los Angeles arrests were made this late. Detectives made 44 arrests, three at the scene of the crime. (Table 5-13).

Results and Operational Suggestions

The principal findings are termed tentative because it is felt further research and analysis is necessary before unequivocal results can be stated. However, these tentative results should allow operational suggestions to be made.

Analysis of the frequency of occurrence by beat showed that robberies had a tendency to cluster. Also, the computerized tabulations indicated a high percentage (65%) occurred on the street and are consequently amenable to preventive patrol.

These results were the main factors in prompting the emphasis given to the incorporation of graphical displays in a police management information system.

In addition, much of the analyses of the preventive force was predicated upon the likelihood of space–time coincidences (related to on-view arrests) shown plausible by these preliminary findings.

The general conclusion based upon this fact is that a geographic graphic display should be provided, whether produced by hand methods (incident map) or by computer, and that preventive units can and should be positioned so that the highest probability of on-view arrests will result.

An obvious desired result is an increase in the percentage of robberies resulting in either on-view or subsequent arrests. Various techniques of statistical analysis may be used in the attempt to identify those factors which are related to an increase in arrest percentage. It appears as though patrol response time is an important factor. However, further analysis is required before it could be stated that response time did not interact with other factors surrounding the robbery phenomenon.

The most promising statistical technique suggested to perform this type of research is known as multiple discriminant analysis. Such methods would allow the identification of interacting factors which discriminate between robberies which result in arrests and those that do not. (Computational details and some illustrative calculations appear in the technical section of this chapter.)

ROBBERY AND THE CHICAGO TRANSIT AUTHORITY

The Operations Research Task Force collected data pertaining to the problem of the fixed-point defense situation discussed earlier. Specifically, the problem was to place preventive patrol officers, in plain clothes, aboard Chicago Transit Authority buses. Riders were considered because bus drivers were reluctant to use flashing signal lights, and the robbers often ordered drivers not to use these emergency flashers. Even when flashers were activated, delays in reporting the signal to police often prevented apprehension of the robbers. Time ran out before an application could be made of the data, but the material is included here for use in other projects. The approach can be generalized to other fixed-point defense problems, such as deployment of bank stakeout teams.

During a 1968–69 period, the Chicago Police Department concentrated on bus robberies. The robberies received a great deal of newspaper publicity. Although few of these robberies had been directed against passengers, public trust regarding safety aboard CTA buses declined because of the publicity and the effect upon passengers who witnessed an armed holdup. Previously, CTA subway stations were targets. In the stations, both waiting riders and ticket booths were targets. When a portion of the CPD Task Force was devoted to subway patrol, the problem was reduced. Similarly the Task Force devoted some of its manpower, along with extra men from District forces, to the bus problem. Robberies decreased.

Obviously, the greater goal of increasing the sense of public safety on all CTA facilities must include factors other than robbery. Assaults, purse snatchings and other disturbances also affect passengers. Recognizing this limitation, the ORTF discussion centers on CTA bus robbery since the data was gathered and processed for this specific crime. The nature of the analysis makes the method applicable not only to bus robberies but other types of crime.

CTA bus robberies provide an excellent example for describing preventive patrol activity in terms of the modeling method. More importantly, several methods of patrol can be examined from a theoretical basis. While the particular methods have not been applied as yet, their development will later provide assistance in planning manpower allocation for similar crime campaigns.

Different approaches and tactics have been undertaken to combat the bus robbery problem. The Chicago Police Department announced that plainclothes policemen would ride the busses and pay fares in an effort to appear as regular passengers. (Chicago Police can use the CTA without payment when in uniform or by showing identification or badges when out of uniform.) This tactic was widely publicized by newspapers and radio. Police hoped for two outcomes: Increase in on-view arrests and deterrence of robbery through publicity.

The number of on-view robbery arrests after a trial period was extremely low, although on-view arrests were made for reasons other than robbery. The tactic was modified to permit plainclothesmen to show their badges or ID and ride without payment. This deterred any observent potential robber on the bus or boarding at the same time as the officer.

Obviously this modification would not increase on-view arrests. The greater police visibility, however, caused a shift of bus robbery activity to the areas of the city where preventive police tactics were not being carried out. However, city-wide, bus robberies decreased over the previous reporting period.

During the same time period, uniformed police in marked cars were stopping the buses at bus stops, boarding the buses and talking with the drivers. The intent of this tactic was, again, deterrence. The frequent stops of buses and the heightened level of patrol car activity in high crime areas along the routes were intended to deter by raising police visibility. While the increased density of police would provide a quick response to a robbery in the area, the increased visibility lowered the chances of police actually witnessing a robbery.

In comparing these tactics with the role of preventive patrol, as described earlier, the police concentrated on the deterrence factor to prevent the criminal event of a bus robbery. Except for an initial attempt, the tactics emphasized visibility of the police presence in the highly probable bus robbery areas rather than displaying their effectiveness through publicized on-view arrests. Unfortunately, there is no way to determine which tactics contributed the most to the decrease. Since robberies in general decreased throughout the same areas where bus robberies had been most common, the decrease in bus robberies might have been for reasons altogether different from the bus campaign.

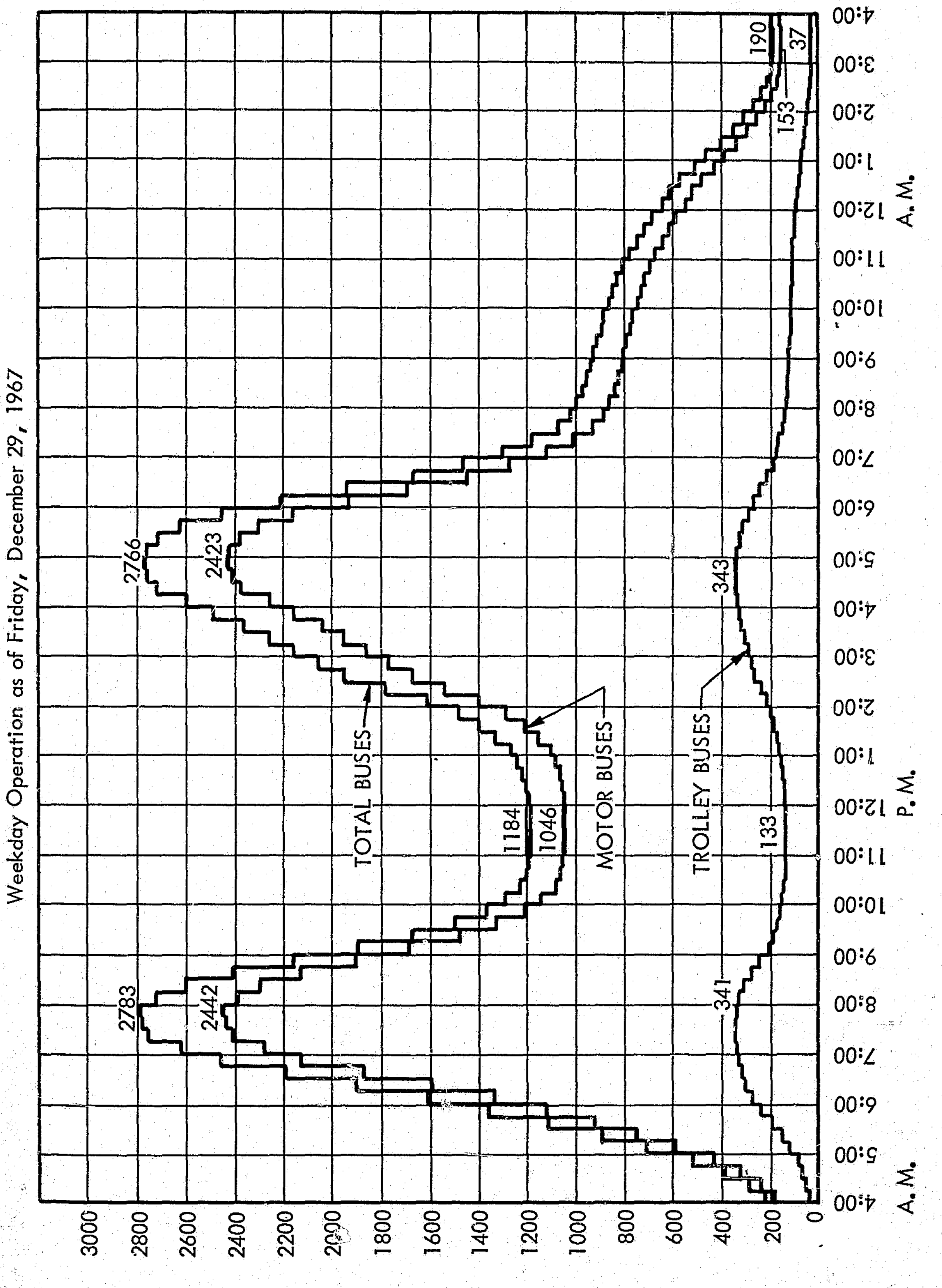
In labor negotiations with the bus drivers' union, the CTA promised to install an exact fare system by late fall of 1969. The system was not specified, but installation of a secure change container that the bus driver cannot open alters criminal opportunity so as to make bus driver robberies virtually impossible. While the police were forced to continue some level of deterrence until the exact-fare system went into effect, the individual victims, drivers, forced the CTA to remove opportunity. This shows how preventive patrol force operates and how victims can alter the initial opportunity for a potential criminal event.

Mathematical attempts to allocate patrol manpower in an optimal manner for the bus robbery problem also emphasize the probability of space-time coincidence as the measure of effectiveness.

Using plainclothes riders of buses is a heavy drain on police resources since it involves two men and an unmarked car to cover one bus. Because these men were drawn from the Task Force during the hours 1800–2000 in high crime areas, the amount of aggressive-preventive patrol was reduced greatly, except on the buses.

Police management needs answers to several questions. Where should men be assigned? How many available men should be assigned to specific areas to maximize the chance of capturing a robber in the act? And what is the probability of capturing a bus robber as a function of the manpower assigned to ride buses? Available data concerning past bus rob-

Figure 5–13 : Chicago Transit Authority
Motor and Trolley Buses Scheduled by 15 minute Periods
Weekday Operation as of Friday, December 29, 1967



beries and information on bus scheduling was used to estimate the likelihood of bus robberies as a function of time and place in the city.

The search effort to detect the bus robbery in progress by a plainclothes passenger is limited to that particular bus. During a time interval Δt_j, of a day, on the order of an hour or more, one man could ride several different buses through a high crime area. Depending upon the frequency of bus service and the length of ride, one man could cover all of the buses traveling through a section of route Δx_i. So, the number of buses that one man can ride through Δx_i in Δt_j is expressed as

$$n = n(\Delta x_i, \Delta t_j) \qquad (34)$$

In like manner, the total number of buses, N, traveling through Δx_i in Δt_j is expressed as

$$N = N(\Delta x_i, \Delta t_j)$$

Figure 5-13 emphasizes the time-varying nature of the number of buses on the streets.

If a section of a bus route has N buses traveling through it in time Δt_j and one man could ride n buses (assuming travel in both directions) for the entire length Δx_i, then the probability of detecting a bus robbery—given that one occurs in segment Δx_i during Δt_j—is $\frac{n}{N}$ per man. If two men covered the area and did not ride the same bus simultaneously, the conditional probability would be $\frac{2n}{N}$,

$$K\frac{n}{N} \leq 1, \quad K = 1, 2, 3\,..$$

Now the probability that a bus robbery will occur in Δx_i during Δt_j—given that a robbery occurs on some bus in the City—can be estimated by taking the total number of bus robberies that have occurred for the past month (or some other historical record) in Δx_i during Δt_j and dividing by the total number of bus robberies for the same historical period that occurred during time Δt_j of the day. We can only estimate this probability by using the relative frequency.

This probability will be written as $P(\Delta x_i, \Delta t_j)$.

Given that a robbery occurs, the probability of being on that particular bus is

$$P(\Delta x_i, \Delta t_j) a_k u(\Delta x_i, \Delta t_j) \qquad (36)$$

where a_k is the number of men (necessarily an integer) and

$$u(\Delta x_i, \Delta t_j) = \frac{n(\Delta x_i, \Delta t_j)}{N(\Delta x_i, \Delta t_j)}, \quad a_k u(\Delta x_i, \Delta t_j) \leq 1 \text{ for all } i$$

which is the ratio of the number of buses to all buses traveling through Δx_i in time Δt_j that one man can ride. The problem of police planning is first (assuming that we will use riders) to maximize the probability of being on a bus that will be robbed given a total of M policemen as riders. Mathematically, maximize

$$\text{Max } P(B/R) = \text{Max}\{\sum_{\Delta t_j}\sum_{\Delta x_i} P(\Delta x_i, \Delta t_j) a_k u(\Delta x_i, \Delta t_j)\} \qquad (37)$$

subject to

$$a_k \geq 0, \quad \sum_{k=1}^{M} a_k = M \qquad (38)$$

Constraint (38) simply insures that we do not assign the whole department as bus riders.

By using the computer to try all combinations of allocating M men and accepting the highest value, the police know the best number of men (a_k) to put in each segment (Δx_i) during time (Δt_j). The maximum value of (37) gives the probability of being on a robbed bus given that a robbery occurs somewhere in the city. (Equation (37) sums over all time increments of the day) By varying the value of M and recomputing, the incremental gain as a function of manpower can be obtained. Thus, all of the questions are answered by the use of these equations.

SIMULATION OF THE CPD TASK FORCE

The objective of the Task Force simulation was to analyze different tactical deployment and to study the implication of changing methods of operation on the total time available for preventive patrol. Two major purposes for writing any simulation exist: to model a time-varying system or to account for actions which occur in a probabilistic manner. The major purpose of the Task Force simulation was to model the activity of Task Force units during aggressive-preventive patrol to determine the actual number of units in patrol status. To accomplish this, the time of occurrence of an activity, the type of activity and the time duration of an activity performed by the Task Force was generated from analytical and empirical probability distributions. Thus the two major purposes of using simulation instead of an analytical model are present in the task Force simulation.

The intent was to take different assignment rules and different manpower levels and use the time and location of actual criminal events to calculate the probability of space-time coincidence. The calculation of space-time coincidence follows the mathematical procedures discussed in a previous section. The allocation methods against street robbery would have been used to assign men to specific geographic sectors in the simulation. When a crime occurred, either the number of men patrolling the region of the crime or the status of the unit specifically assigned to the sector of the crime would be checked. Probability of space-time coincidence would be computed on the basis of unit availability.

Time did not permit using the Task Force simulation at its full potential to test different assignment rules by comparing the computed probability of space-time coincidence. The results of the simulation described here assume a uniform geographic distribution of crime and do not identify patrol units with specific geographic sectors within the larger patrol area. The area used was realistic in that the actual miles of streets and alleys were entered, as were robberies actually occurring in this area and the actual times of occurrence, to calculate space-time coincidence.

While the results of this simulation do not show the potential performance of preventive patrol in a high crime area, the details of the simulation are included for several reasons. First, a great deal of descriptive information concerning the nature of aggressive-preventive patrol by the Task Force is contained in this simulation discussion. Second: the ability to model and to verify a simulation of a preventive patrol unit might interest other researchers.

Simulation provides opportunities to study alternative methods of preventive patrol without the complexities of field tests. This does not mean that the field tests are unnecessary; it means that effects can be better anticipated and some alternatives discarded without a field test.

The Task Force, unlike the beat patrol force, does not receive assignments from the Communications Center. Task Force officers take "flash" messages concerning crimes-in-progress or descriptions of wanted vehicles or persons involved in just-committed crimes for the immediate area. As a consequence, no data bank existed, at the time of the study, showing the amount of time spent on street stops, arrests, vehicle stops and premise checks. So the actual number of Task Force units actively patrolling an area was unknown. The commander of the Task Force and a police member of the Operations Research Task Force developed a simple activity report. Each unit assigned to the First Area Task Force was requested to note the nature of the activity, the time it began and the time completed.

The initial results were sufficiently interesting that the Task Force's commander suggested a longer test period. All of the activities recorded in the first period were consistent with department philosophy regarding aggressive-preventive patrol. By the simple procedure of blackening a time-square on the report sheet for activities such as premise checks, vehicle stops, questioning suspicious persons, car service, lunch, etc., the recording was simplified. However, the blackened portions of the report sheets, when consolidated, showed that a much smaller percentage of the deployed force was in an active patrol status at a given time than Task Force managers had assumed. This meant that few units would be available to detect a street crime-in-progress at any given time during an evening. In many cases, units that were not in active patrol status would also miss "flash" messages broadcast over the radio. These "Down Time" results are shown in Figure 5-14. Each block represents time out-of-service.

During the additional test period, the Task Force units were requested to register the odometer readings of the patrol vehicles to the nearest tenth-mile at the end of each activity. Thus a distribution of patrol speeds could be obtained for use in search models. The total data used in the simulations consisted of three weeks of activity reports from the First Area Task Force for the period 9–29 January 1969. While some Task Force units were deployed during the day, the activity reports were taken only for units on duty from 1800 hours to 0200 hours.

Activities which remove Task Force units from patrol status are self-initiated unless they are responding to an emergency or "flash" radio message. From the activity reports, 17 categories of activity were observed which had frequencies of occurrence from 459 to 3 during the recording period. For the 21 days, the overall average of down-time was 32.7 percent. This refers to all reasons for going down from patrol. The average is possibly useful for administrative planning purposes, but the actual distribution of availability shows certain times when the number of units in patrol status is very small. The data were used to determine the relative frequencies of different activities. This frequency rating is shown in Table 5-14.

Normally, arrests resulted mostly from the first three activities: stop-and-frisk, street-stop/license check and traffic stop. A police officer in the Operations Research Task Force did the categorization of

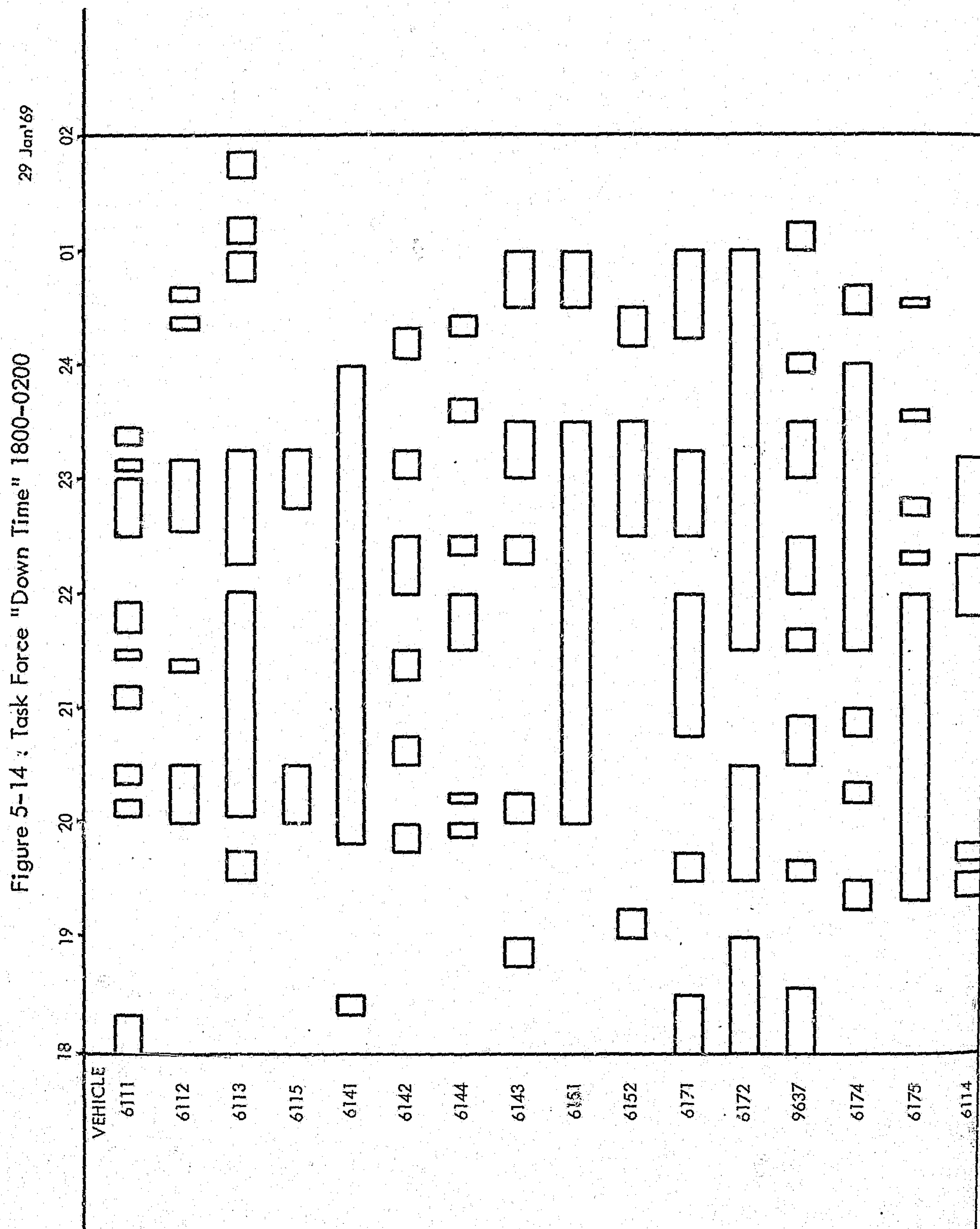


Figure 5-14 : Task Force "Down Time" 1800-0200

Table 5-14

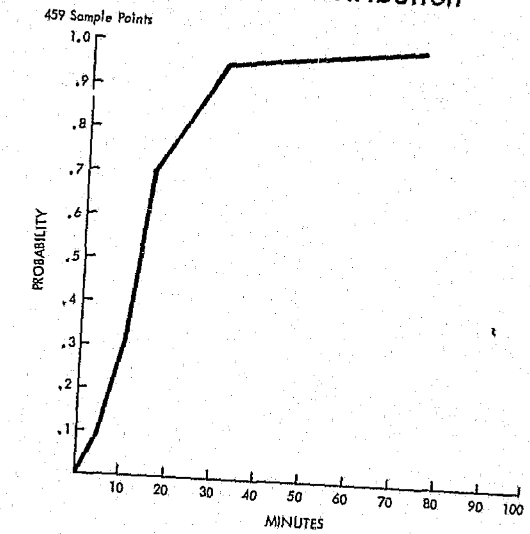
Summary of Task Force Activity

Activity name	Number of occurrences	Minutes expended (total)
Stop/frisk	459	7,917
Street stop/license check	64	1,135
Traffic stop	319	4,787
Processing arrests	115	11,925
Personals	43	2,130
Report writing	46	2,010
Curfew violations	15	370
Car service (gas, radio, maintenance)	88	2,370
Premise check	3	45
Stakeout	9	340
Assist citizen	6	115
Showup	3	220
Investigation	15	680
Assist police (alarms, in progress, searches, etc.)	49	1,480
Search warrant	3	835
Lunch	226	6,820
Roll call	19	369

the activities, and he indicated that precise distinction between the three activities did not exist in his mind or in the written activity reports. The activities distinguish the stopping of pedestrians (acting in a suspicious manner or resembling persons described in "flash" messages) from the halting of a vehicle. A vehicle would be stopped for traffic code violations, resemblance to a car used in a crime or because the license number was listed on a "hot sheet" of wanted cars. If persons in the vehicle acted in a suspicious manner, the Task Force unit's standard practice was to call the Communications Center to determine if either the vehicle or the occupants were wanted by the police. The Communications Center used an on-line computer inquiry system for answering these queries. However, the actual distinction, useful for purposes of definition, seems to make little difference for simulation purposes. The three activities are summed, and the percentage of arrests from this total was used in the simulation. Also the mean time of these activities was nearly the same.

"Roll call," as used in the preceding table, covers those cases where the activity report indicated that a unit began patrol later than 1800 hours or returned to the station prior to 0200 hours. Actual roll call takes place one-half hour before the start of a watch. This activity category indicates some type of work, then, within the station when used in the simulation. "Curfew" refers to the stopping of youths after the curfew hour. The activity can result in the issuance

Figure 5-15 : Stop-and Frisk , Service Time Distribution



of a summons or an action taken to guarantee the immediate return to home for the violators.

Because of several small sample sizes, the activities of premise check, stake-out, assist-citizen, show-up and investigation were combined. The service times for these activities were combined to form a time distribution. The sum of occurrences was used to estimate the frequency of occurrence for this joint activity. Stake-out is a rather rare activity that occurs when Task Force units are used to augment other forces in a planned raid or capture. Show-ups occur when a suspect is arrested and taken to a police station for identification. Investigation and search

Figure 5-16 : Street-stop/license-check service time distribution

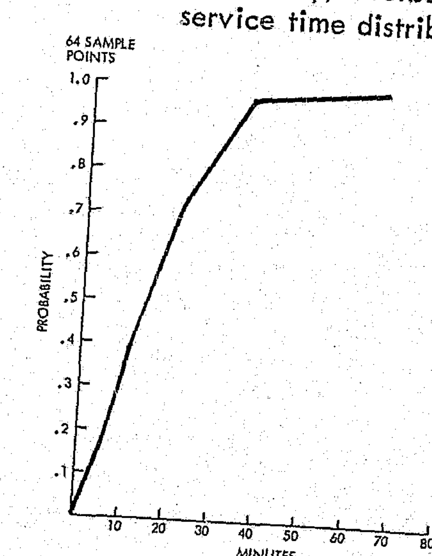
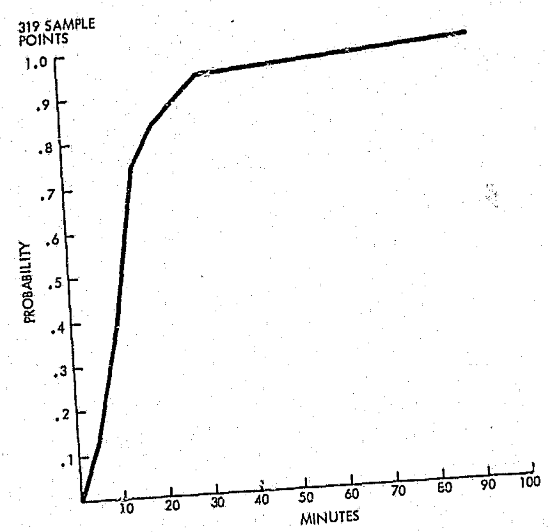


Figure 5-17 : Traffic-stop service time distribution



warrant activities can result from an arrest for possession of narcotics or dangerous drugs and the subsequent search of the persons[1] residence. While these activities had small sample sizes, they were not combined into a single distribution because of their dissimilar service times.

Histograms of the service times for 10 activities were made from the data. A distribution for the activity of search warrant was assumed uniform over the range of three samples. From the histograms, cumulative distributions of the probabilities associated with service times were drawn. (Figures 5-15 through 5-26)

The time for lunch was always recorded as 30 minutes. A sample of 215 lunch periods was used to

Figure 5-19 : Personals, service time distribution

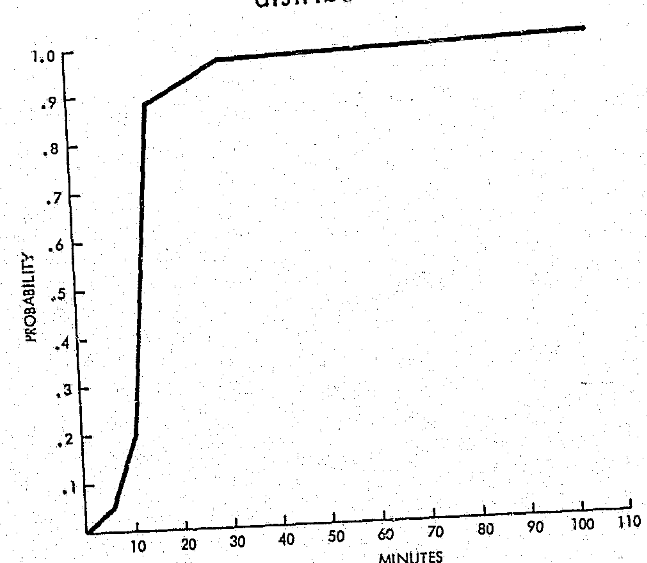
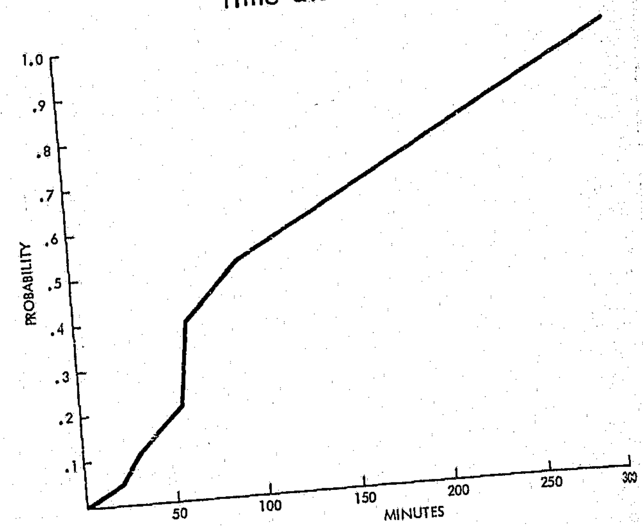


Figure 5-18 : Processing arrests, service time distribution



obtain the relative frequency of lunch occurrence with time. In the simulation, every event except lunch and the processing arrests was assumed to occur at random. The times for lunch showed the marked preferences of the units, as might be expected. The largest percentage of lunch breaks occurred between 2100 and 2300 hours, as illustrated above in Figure 5-26. Generation of lunch and arrest events is discussed in the stochastic simulation section.

Deterministic simulation, as the name implies, does not use assumed or empirical distribution of service time. Event occurrences and their time duration, for

Figure 5-20 : Report writing, service time distribution

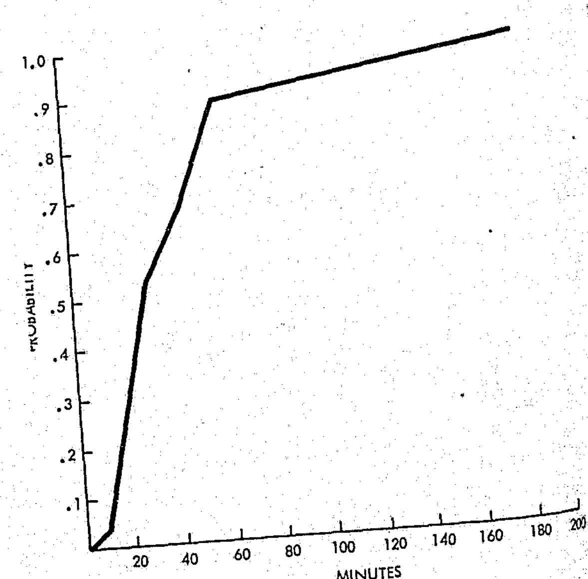
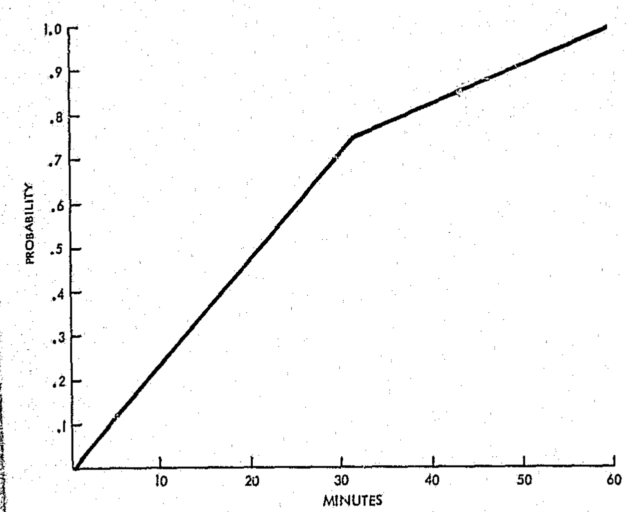


Figure 5-21 : Curfew violations, service time distribution.



the Task Force units, were simply taken from one week of activity reports filled out by the officers. This type of simulation could be used also with the radio dispatch summary tapes to determine patrol status of beat cars during a watch period.

The deterministic simulation was programmed for several reasons: to estimate the space-time coincidence probability using actual data, to investigate the effect on patrol time of excluding certain Task Force activities and to verify the results of a stochastic simulation. The principal disadvantage of the deterministic simulation is the inability to study the change in estimated space-time coincidence probability by varying the manpower. This was the principal reason for developing to stochastic simulation.

Stochastic simulation, as its name implies, uses empirical distributions for activity occurrence and the service time for the activity. In addition, the speed of Task Force unit patrol and the time of duration for a robbery were selected from distributions. The service time, speed of the patrol car or the duration of a robbery was selected from a distribution by the draw of a random number generator in the computer.

To select the mean time between any activities for a particular Task Force unit, the total number of activities (excluding arrest processing and lunch) were divided by the total number of units deployed for the 21 days to determine the mean times between these activities. Activities or (endogenous events) were assumed to follow a Poisson distribution in time. The endogenous events were then generated by drawing a time from a negative exponential distribution with a mean equal to the mean time between activities

Figure 5-22: Car service, service time distribution.

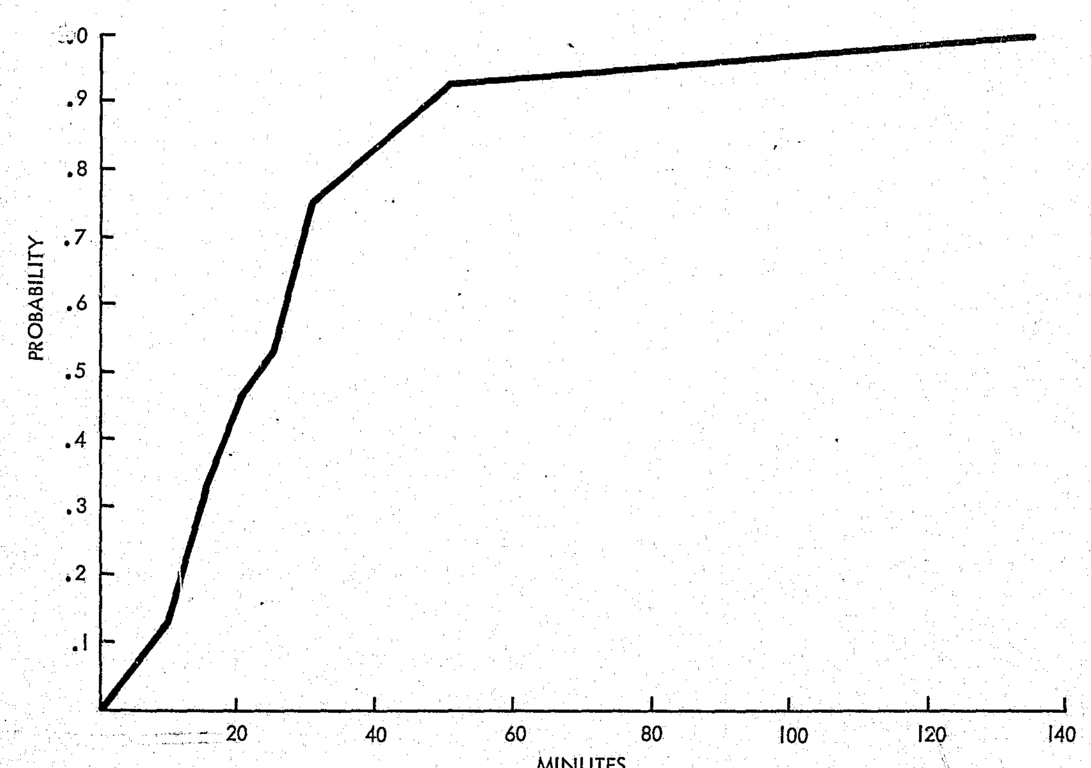


Figure 5-23: Combined service time distribution for stake-out, assist citizen, premise-check, show-up, investigation.

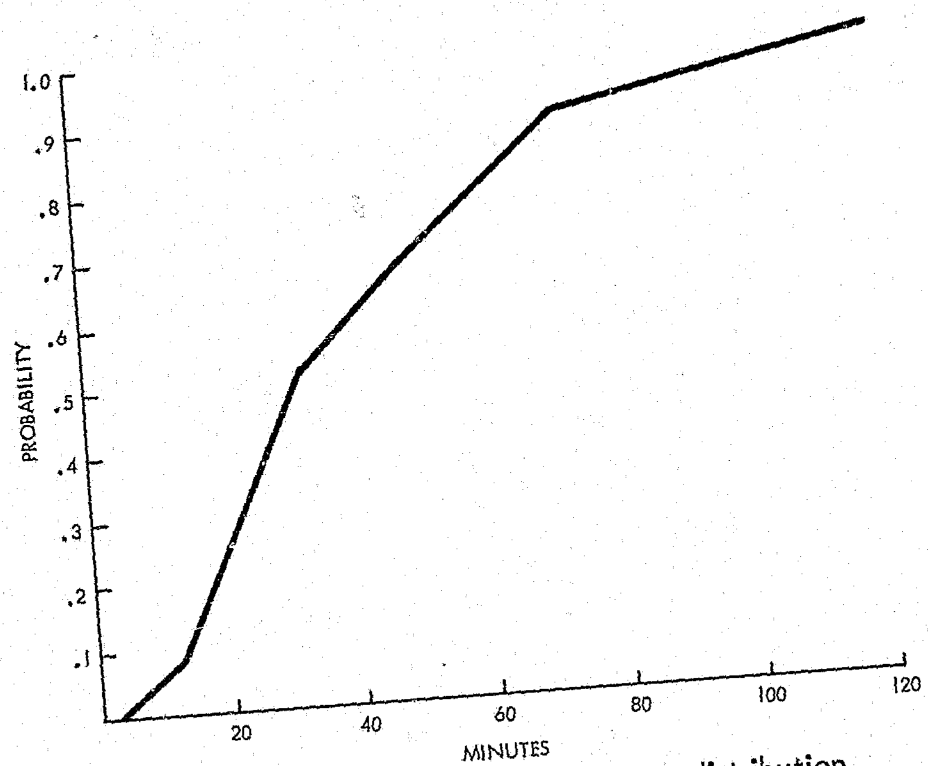


Figure 5-24: Assist police, service time distribution.

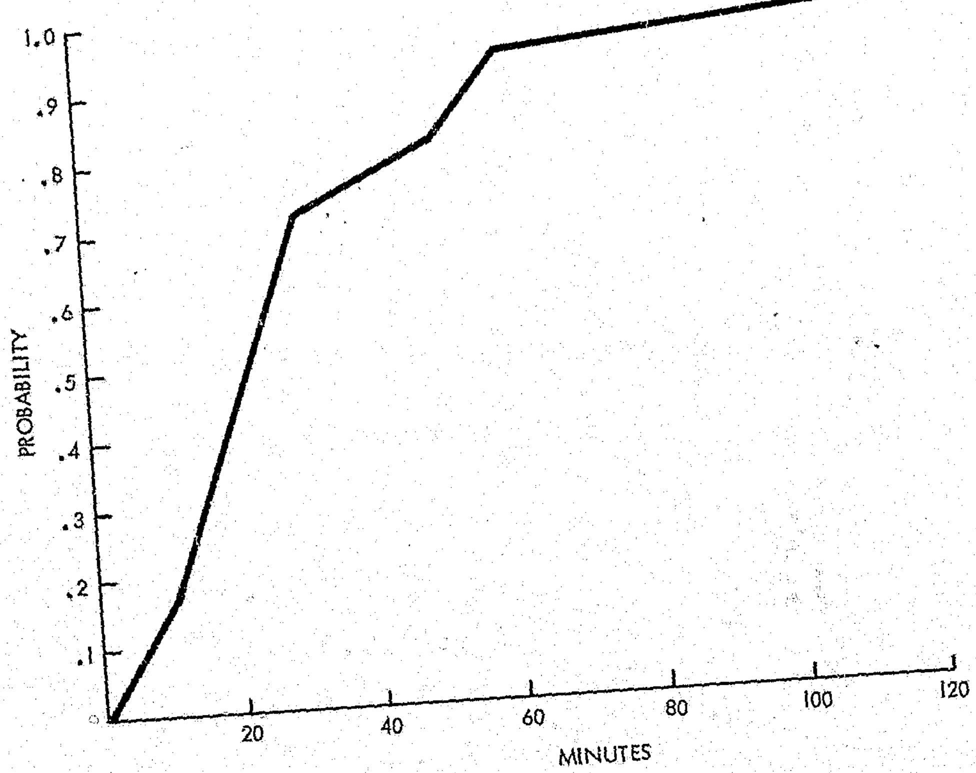
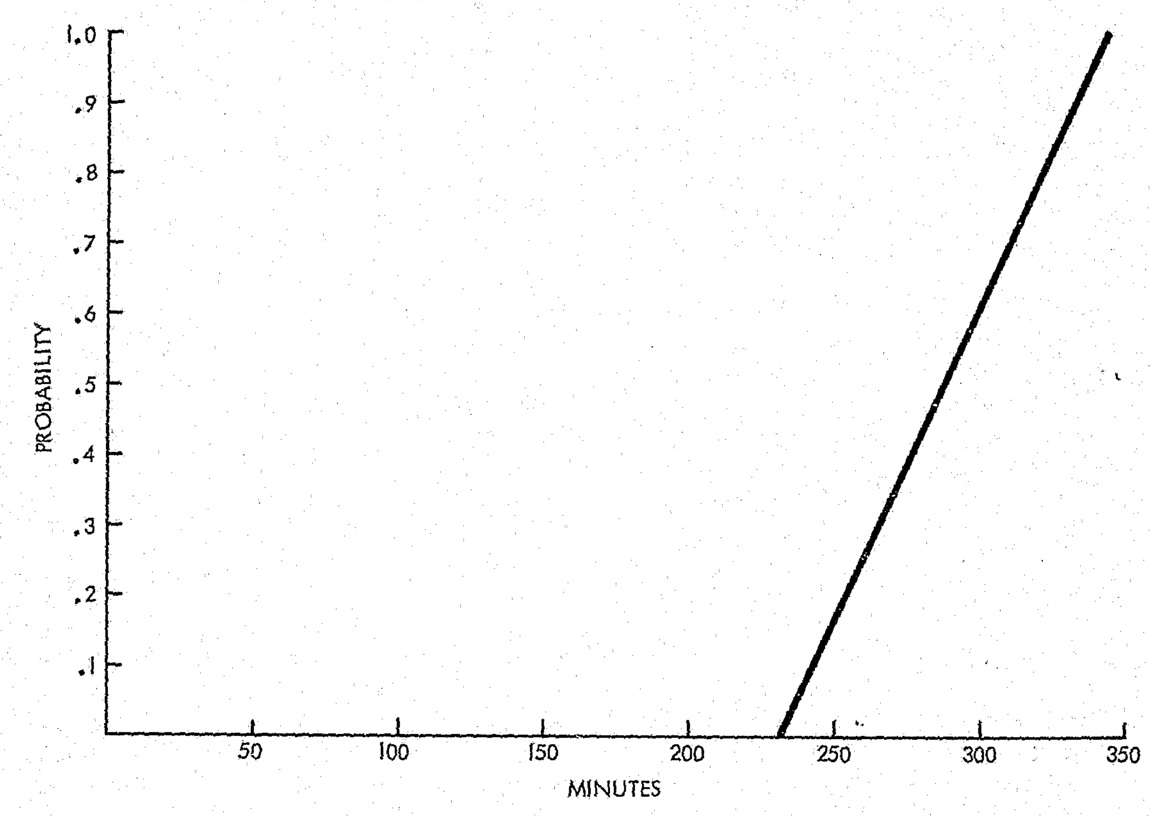


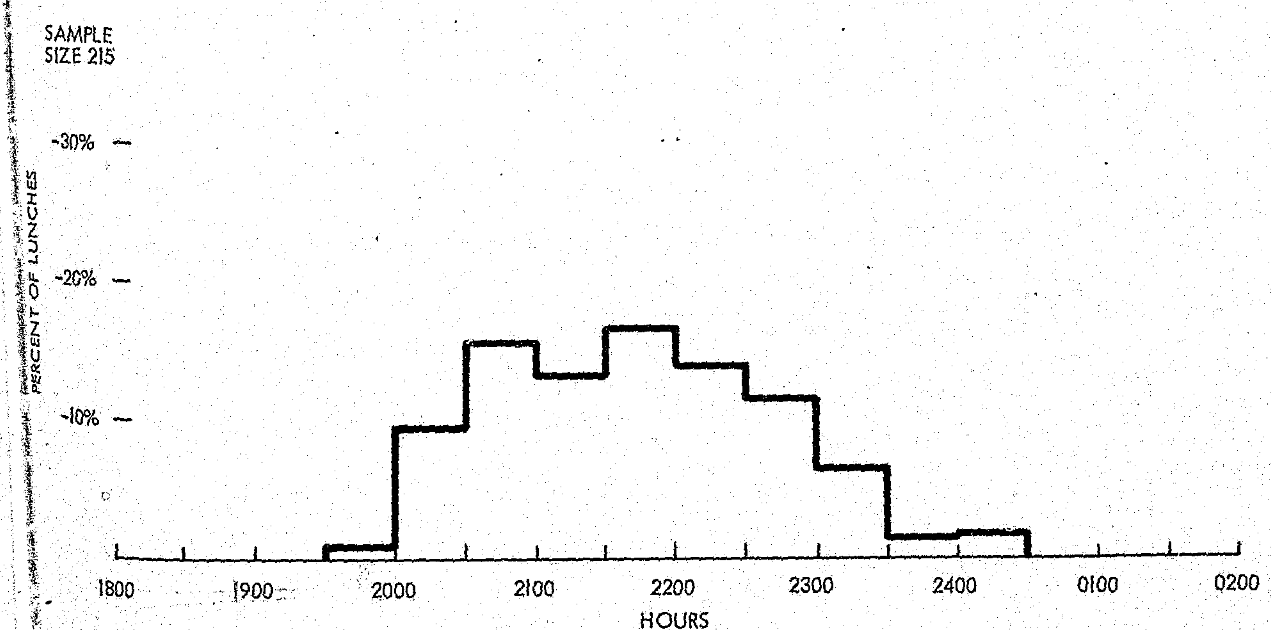
Figure 5-25: Search warrant, service time distribution.



calculated from the data. Each time a Task Force unit is available or on patrol status, the simulation program generated its next time-out-of-service for another activity. Another subroutine used a program to determine the type of activity (street-stop, premise-check, etc.) based on the relative frequency of the different activities with respect to each other. Another subroutine then calculated the amount of time out-of-service for this particular activity.

It was noted that arrests normally resulted from

Figure 5-26: Lunch distribution for patrol period



three activities: stop-and-frisk, street-stop/license check and the traffic-stop. Each time one of these occurred, a draw was made to determine whether an arrest would occur. On the basis of the 21 days of data, 13.6 percent of these cases resulted in an arrest. If an arrest occurred, the subroutine selected the amount of time required to process the arrest. This was added to the Task Force unit's time out-of-service.

Lunch could not be handled as a random event since the data showed a marked preference by officers for certain eating times. Whenever a car was free in a particular time interval when lunch was eaten, the unit went through a draw function which assigned the same percentage of units to lunch as shown in the original 21-day sample. If fewer than the normal number were actually assigned during a given interval, the probability of drawing a car in the next interval for lunch was increased. This resulted in an almost certain assignment for lunch in later intervals if a unit had not received lunch during the earlier intervals. As the data revealed, not all units took a lunch break, and this simulation could result in some units not receiving lunch. Lunch was always given a time of 30 minutes. In the simulation, no unit could be assigned two lunches.

As in the deterministic simulation, the number of units in patrol status at the time of a robbery (an exogenous event not generated inside the patrol unit) was obtained and used to compute the probability of space-time coincidence. Each unit in the stochastic simulation was given a unique number. This was done so that particular cars could be assigned to definite geographic areas, and the status of cars in the particular areas could be determined. This permits the testing of different assignment rules and does not require assumptions about uniform distributions of crime or Task Force units.

Verifying the Results

Verification of any simulation is a process open to debate. One of the main purposes of the Task Force simulation was to take units in and out of patrol status in a realistic manner. No verification problem exists with the deterministic simulation unless the accuracy of the data is questioned. Since the data covered 21 days and consisted of 278 reports, the sample size and makeup was considered adequate. The deterministic simulation was then used as the real world, and the stochastic simulation was compared to it.

The deterministic simulation covered seven days, 9–15 January 1969; the number of Task Force units on the street varied from seven units to seventeen during this period. Two factors were used for comparison: average car availability and distribution throughout the eight-hour period of available cars. Expected values of car availability are the only inputs necessary for analytical studies such as those discussed in the preceding section on mathematical modeling.

More realistic treatment would consider differences of car availability in different time periods of the watch. For using the analytical expressions, a comparison of car availability as computed from the deterministic and stochastic simulations was considered adequate. The more stringent test of car availability throughout the watch tests the assumptions of endogenous event occurrences and the service time distributions. Verification of this criterion permits us to use the stochastic simulation as the real world, insofar as car availability during a watch is concerned.

The Chi-square test was used to test the hypothesis that no difference existed between the deterministic and stochastic simulation values. To test for any difference between the average car availability, the mean number of units available were compared. Samples of car availability were taken every 15 minutes from the eight-hour period for both simulations, and the mean was computed. The value obtained was 1.2220 for six degrees of freedom. This means that the hypothesis that the deterministic result and the stochastic result are generated from the same process and cannot be rejected at the 5 percent level. This is interpreted as a very close agreement between the stochastic simulation and the deterministic simulation, as far as mean car availability is concerned. (See Table 5-15)

Table 5–15
Comparison of Deterministic and Stochastic Simulation Results

January—	Task force units	Deterministic simulation (mean cars available)	Stochastic simulation (mean cars available)
9	10	8.41	8.18
10	9	7.71	6.98
11	9	6.73	6.73
12	14	9.65	9.58
13	20	13.31	16.09
14	7	5.01	5.85
15	13	8.04	9.86

Computing the Chi-square statistic as
[Deterministic mean value (j)—Stochastic]² mean value (i)
Deterministic mean value (i)

Table 5–16
Chi-Square Test Results

January—	Task force units	Chi-square statistics	Degrees of freedom
9	10	43.459	95
10	9	27.958	95
11	9	46.086	95
12	14	46.598	95

To verify car availability during the day, the number of available cars for both programs was found at five-minute intervals on each of four days. The Chi-square statistic on the comparison of available cars at each time interval was computed. The results of the computer processing of the four (one for each day) Chi-square tests is shown in Table 5-16.

Clearly the hypothesis that the systems are the same cannot be rejected at the 5 percent level. For 95 degrees of freedom, the Chi-square statistic must exceed 113.145 to reject the hypothesis at that level. The result is interpreted as close agreement between the time distributions observed for four days and the simulation results.

This extremely close agreement existed for four days. For the purposes of simulation in checking police deployment methods and obtaining statistics for analytical equations, the correspondence between the simulations is acceptable. The very close agreement on mean car availability and the very close agreement for four days: time distributions of car availability demonstrates a close modeling of the real world in the stochastic simulation.

As far as further use of this stochastic simulation is concerned, it will be considered as a good representation of the Task Force patrol activity. In the use of the stochastic simulation for deployment studies, no conclusions or recommendations will be made unless major differences can be shown.

Table 5–17
Probability of Space-Time Coincidence

Number of units in area	Number of robberies in area	Mean probability of space time coincidence in area
10	2	0.00567
9	6	0.00451
9	3	0.00096
14	6	0.00556
20	6	0.00976
7	3	0.00294
13	6	0.00315

Space-Time Simulation Estimates

Using the assumptions of a uniform geographic distribution of robberies in the patrol area, the following probabilities of space-time coincidence were obtained for the seven days of the deterministic simulation. (See Table 5-17)

Using average values of these variables, 12 patrol units would expect to achieve space-time coincidence at least twice every 100 days of patrol when using random patrol in this area. Naturally, the availability of these men to respond to crimes-in-progress and to search the area for criminals answering descriptions made by victims would increase their arrests over this estimated figure. But this action hardly fits the preventive patrol model.

As a comparison, 50 percent of the street-stops, traffic-stops and stop-frisks were deleted on a chance basis from this simulation. In other words, every time one of these events occurred, the computer used a random number generator to discard 50 percent of the events. This increased the amount of time each unit spent in preventive patrol. This produced the results in Table 5-18.

While each of the mean values for the seven days has increased for every day but one (It remained the same.), the expected number of space-time coincidences increased to at least 2.7 or nearly 3 for the 100-day period with 12 units in patrol. This was done by altering the number of stops, not by increasing the manpower.

These numerical results cannot be directly compared to the actual Task Force performance on these days. This is because the Task Force was not assigned in a uniform manner throughout the area, and some patrol was conducted outside the area used in this simulation. The stochastic simulation would permit a calculation of space-time coincidence with any level

Table 5–18
Probability of Space-Time Coincidence With Adjusted Car Availability

Number of units in area	Number of robberies in area	Mean probability of space-time coincidence in area
10	2	0.00567
9	6	0.00462
9	3	0.00504
14	6	0.00630
20	6	0.01039
7	3	0.00336
13	6	0.00577

of manpower. The time of the robbery does appear to make a difference in the calculation, however, since the mean probability of space-time coincidence is not consistent with varying levels of manpower. As an example, the mean value on the second day, with nine men assigned, was less than the mean value on the last day with 13 assigned.

The probability of space-time coincidence is directly proportioned to the number of the units in the assigned sector case, and nearly so in the non-assigned sector case, for the robbery example. When criminal events cluster in time and space, and when patrol units are not uniformly available, simulation would be expected to provide better estimates of space-time coincidence than the analytical expressions stated earlier, using expected values of the variables. These conditions hold in Chicago; hence, simulation looks like an excellent tool. These simulations could be used for estimating the probability of space-time coincidence for other types of criminal events by changing the time duration of the criminal event and, possibly, the patrol speed distribution.

The conclusions and recommendations for the deployment of preventive patrol units are based on a systems analysis of the preventive patrol role, an analytical modeling of random patrol and the results of two detailed studies of street robbery and bus robbery. In brief, some crimes will cluster in high crime regions of the city. The use of historical data and a method of manpower allocation based on an analytical patrol model offers a potential gain of as much as a factor of 10 in the probability of achieving space-time coincidences. The absolute improvement, however, is small so the deployment of preventive patrol units which maximizes space-time coincidence denies opportunity and exercises a maximum deterrent effect. In addition, it minimizes expected travel time to a crime-in-progress call.

The validity of the predicted space-time coincidence values is unproven and the validity of the analytical patrol model has not been verified. Uncertainties associated with the models make the use of the predicted probabilities of space-time coincidence of questioned value in comparing effectiveness of preventive patrol units with effectiveness of beat patrol units or detective forces. The uncertainties, however, should not cause significant error in the deployment of preventive patrol units. The decision to use preventive patrol forces, or the evaluation of preventive patrol units in comparison with other police units can be readily accomplished using other measures of effectiveness.

Thus, although the predicted values of space-time coincidence are unverified, their use to deploy preventive patrol units is recommended. Further study to verify actual values is also recommended.

PREVENTIVE PATROL: TECHNICAL ANALYSIS

This technical analysis of the preventive patrol function was developed over the period of the research project. First, a detailed systems analysis of preventive patrol was undertaken to determine the relationship of preventive patrol to the rest of the police department and to specify the possible outputs of the preventive patrol activity.

Since the intent of the overall project was to address the resource allocation problem, mathematical models of preventive patrol activity were sought. Unless the activity can be described in some mathematical sense, the allocation of police resources in a quantitative manner cannot be done for the function of preventive patrol. The patrol models were elaboration on the work of previous researchers. Other quantitative models or measurements can be used to allocate preventive patrol resources, but the models were chosen because of their explicit consideration of crime density, crime type and method of police patrol.

The measured output of the patrol models is the probability of space-time coincidence. This is an estimate of the probability that a preventive patrol unit will be at the same spot at the same time as the occurrence of a criminal event. This section discusses in more detail the reasons this probability should be maximized.

Chicago had an established preventive patrol force, the Task Force. A digital computer simulation of this unit's activity was completed, and it will permit a user to compute the probability of space-time coincidence as a function of manpower. The write-up is included as a comprehensive description of a major preventive patrol force. Successful modeling of actual Task Force activity was achieved. This indicates that different patrol tactics can be simulated with historical crime data to determine which ones yield the highest probability of space-time coincidence. Field tests can then be conducted with the tactics which look the most promising. The simulation results could also be used to assist in the design of the field experiment.

Finally, a ratio of arrests to the product of reported crimes and available preventive patrol time is proposed as an overall measure of effectiveness for a particular region within the city. This measure indicates whether the maximization of the probability of space-time coincidence has increased patrol arrests or decreased reported crime as a function of patrol time.

Mathematical Models

The mathematical models used for patrol activity are reviewed here for their ability to estimate the probability of placing a patrol unit at the same place and time as a criminal event, the probability of space-time coincidence. The objective function used to place units is the maximization of space-time coincidence. The mathematical basis for this placement is discussed.

Two types of patrol placement were considered. The first type restricts each patrol unit to a particular sector, thereby preventing units from overlapping their activities. Since two units would the cover twice as much patrol surface as one unit, this type of placement is called a linear addition of coverage with manpower.

The second type of placement adds additional units to a larger area so that overlap between each patrol unit can occur. This type of placement results in an exponential addition of patrol surface coverage rather than the linear addition case. This is illustrated in Figure 5-2, presented earlier. For the only numerical examples (patrol against street robbery), there is very little difference in the probability of space-time coincidence for these two methods. This was illustrated in Figure 5-3.

There could be a much larger difference for other types of crime, such as burglary, which has a longer time span for commission, or for a case where significantly larger numbers of patrol units are available. Administratively, the linear addition model will be called the assigned-sector case, and the exponential addition model will be called the non-assigned sector case. Each of these cases is later used in an allocation of patrol units against bus robbery and street robbery.

Previous work in this area, of public systems[4] and in patrol[10] specifically, has concentrated on analytical expressions of calculating space-time probability to estimate the occurrence of on-view arrests. As such, the formulas included an availability factor which gave the average time that patrol units were actually in patrol status. Much of the work in this paper used simulation or treats the precise time and location of a criminal event explicitly in the computation of the probability of space-time coincidence. For these reasons, many expressions do not contain any availability factor; the expressions are contained in a computer computation which uses the actual number of units on patrol status at the time of the criminal event.

Certain mathematical formulations in this section, such as those on verification, have not been pursued for numerical results. None of the mathematical models have been subjected to field test verification of the accuracy of their numerical results. Both of these situations indicate the need for further work. The latter failure of verifying the models: numerical results is not serious in relation to the purpose of maximizing the probability of space-time coincidence by comparing different patrol deployments. It is a serious problem only if a decision is sought as to whether men should be placed in preventive patrol units or whether the men should be assigned to other units. This material can serve as the point of departure for future work.

These symbols and definitions will be used throughout the discussion:

P_{st} (Probability of space-time coincidence.)
K (Number of preventive patrol units.)
S (Speed of patrol for a unit.)
T (Time that a criminal event is viewable to a patrol unit in a manner that gives evidence of a criminal event.)
B (Number of miles of streets and alleys per square mile of the city.)
A (Area in square miles of the overall patrol region.)

The product BA is used in numerical computations since the actual number of miles of streets and alleys was taken from city maps for particular patrol regions. The average value B could inject serious inaccuracies for specific sections of some cities because of an uneven placement of parks or other geographic features.

TFUNITS (Quantity used in a computer simulation to indicate the number of units in patrol status at a given instant of time.)
ρ (Probability that preventive patrol unit is in patrol status.)
P (Probability of a patrol unit detecting a criminal event given achievement of space-time coincidence.)
N (Number of criminal events per unit of time.)
D (Number of police detections per unit of time.)

Assigned Sector Model

When using the assigned sector method (linear addition of patrol activity), the probability of any particular unit not achieving space-time coincidence with a criminal event is

$$1-\frac{KST}{BA}, \quad \frac{KST}{BA}\leq 1 \tag{1}$$

In equation (1), K is the number of assigned sectors as well as the number of patrol units. The total number of miles of streets and alleys in a patrol sector is BA/K, and the number of miles covered by the patrol unit during the time the criminal event is viewable is ST. The fraction composed of ST divided by BA/K is the probability of space-time coincidence in a sector. As K increases, the assigned sectors of patrol decrease in size, and the distance ST covered during a criminal event covers a greater proportion of the sector. If a patrol unit is in patrol status with the probability ρ, the probability of a particular unit achieving space-time coincidence becomes

$$P_{st}=\rho\frac{KST}{BA},\quad \frac{KST}{BA}\leq 1 \tag{2}$$

In a computer simulation that assumes a uniform distribution of crime throughout A, the probability of achieving space-time coincidence is computed from

$$P_{st}=\frac{(\text{TFUNITS})ST}{BA},\quad \frac{(\text{TFUNITS})ST}{BA}\leq 1 \tag{3}$$

Where TFUNITS is the number of patrol units out of K that were in patrol status at the time of the criminal event.

If the location of a criminal event is isolated to a particular patrol sector in a simulation, the probability of a space-time coincidence is either 0 or

$$\frac{KST}{BA},$$

depending on whether the unit for the particular patrol sector is in patrol status at the time of the criminal event. To summarize, this formulation is useful for simulations that use the time and location of criminal events with the patrol status and patrol sector location of preventive patrol units.

Equation (3) is useful for a simulation which does not consider crime location and assumes a uniform distribution of crime throughout A and an equal ρ for all K units.

Equation (2) is used in analytical formulations which do not consider time or location of criminal events.

Non-Assigned Sector Model

If the patrol units were permitted to patrol at random instead of remaining K assigned sectors, the probability of a particular unit not achieving space-time coincidence is

$$1-\rho\frac{ST}{BA},\quad \frac{ST}{BA}<1 \tag{4}$$

The probability of none of the units achieving space-time coincidence is

$$\left(1-\rho\frac{ST}{BA}\right)^K \tag{5}$$

where K is the number of patrol units in A. In this case, the probability of at least one unit achieving space-time coincidence is

$$P_{st}=1-\left(1-\rho\frac{ST}{BA}\right)^K \tag{6}$$

If K is a reasonably large number, equation (6) is closely approximated by the expression.

$$P_{st}=1-\exp\left(-\rho\frac{KST}{BA}\right) \tag{7}$$

In computer simulations TFUNITS is used in place of the product of K and ρ.

While the difference for the particular crime type of robbery in this paper shows negligible differences between the assigned and non-assigned sector cases, other situations would result in greater differences. For that reason, a more thorough discussion of the differences appears warranted.

Assuming a uniform distribution of crime in A, a criminal event will occur in a particular sector with the probability $1/K$. Considering the probability that this particular patrol unit is in patrol status, the probability that $P_{st}=0$ is

$$\frac{(1-\rho)}{K} \tag{8}$$

Otherwise P_{st} is equal to the value of equation (2). In the non-assigned sector case the probability that $P_{st}=0$ is

$$(1-\rho)^K \tag{9}$$

Which is the event that every preventive patrol unit in A is out of patrol status at the same instant. The comparisons of equations (8) and (9) for different values of K and ρ are shown in Figures 5-27 through 5-30. Except for cases of low ρ and small values of K, as illustrated in Figured 5-27 and 5-28, the non-assigned sector case normally gives the greatest chance of achieving a non-zero value for P_{st}.

Since the differences between P_{st} for the assigned and non-assigned sector cases for the robbery example is negligible until K becomes very large, the non-

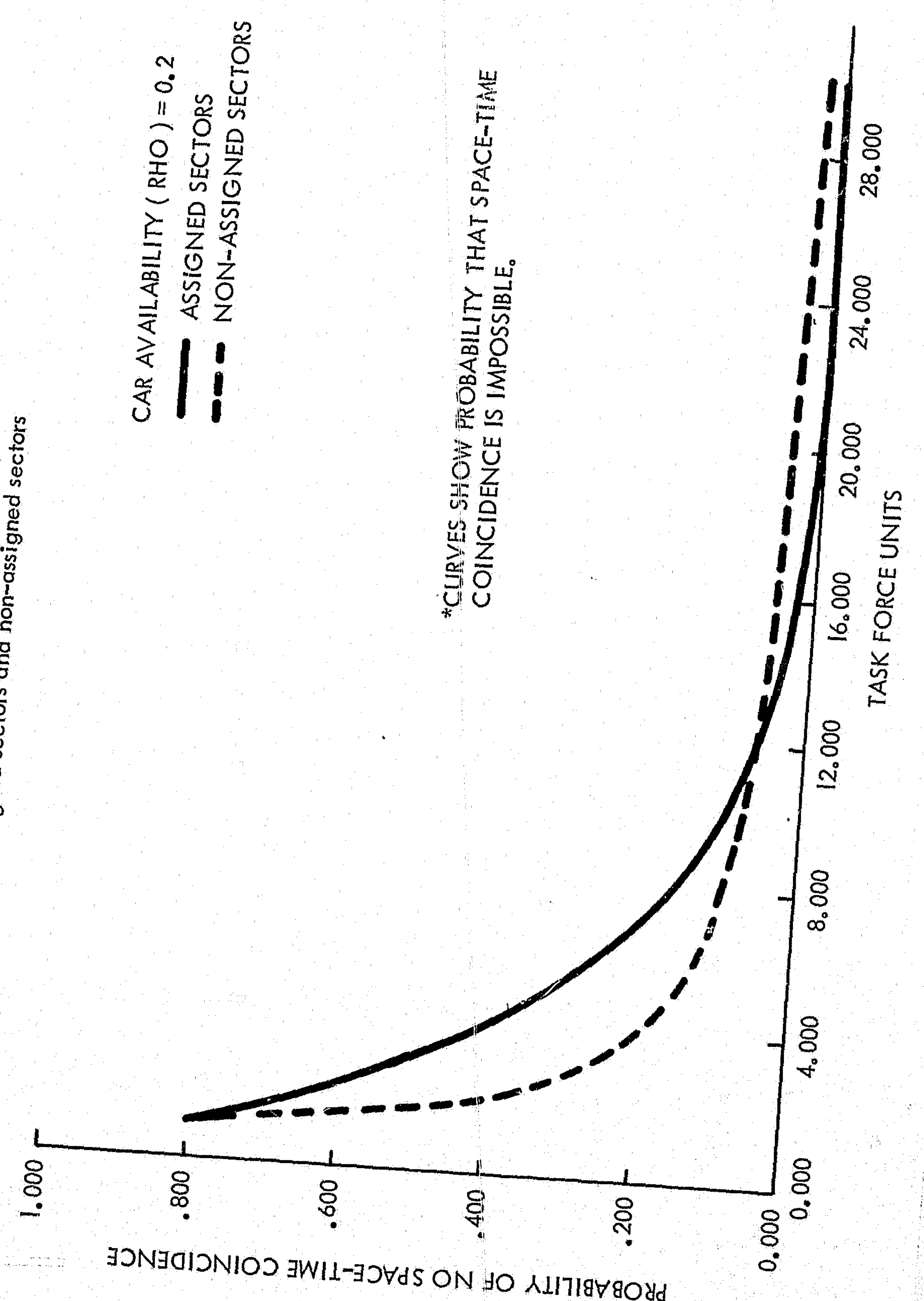


Figure 5-27: The probability of no space-time coincidence* as a function of task force availability for assigned sectors and non-assigned sectors

Figure 5-28: The probability of no space-time coincidence* as a function of task force availability for assigned sectors and non-assigned sectors.

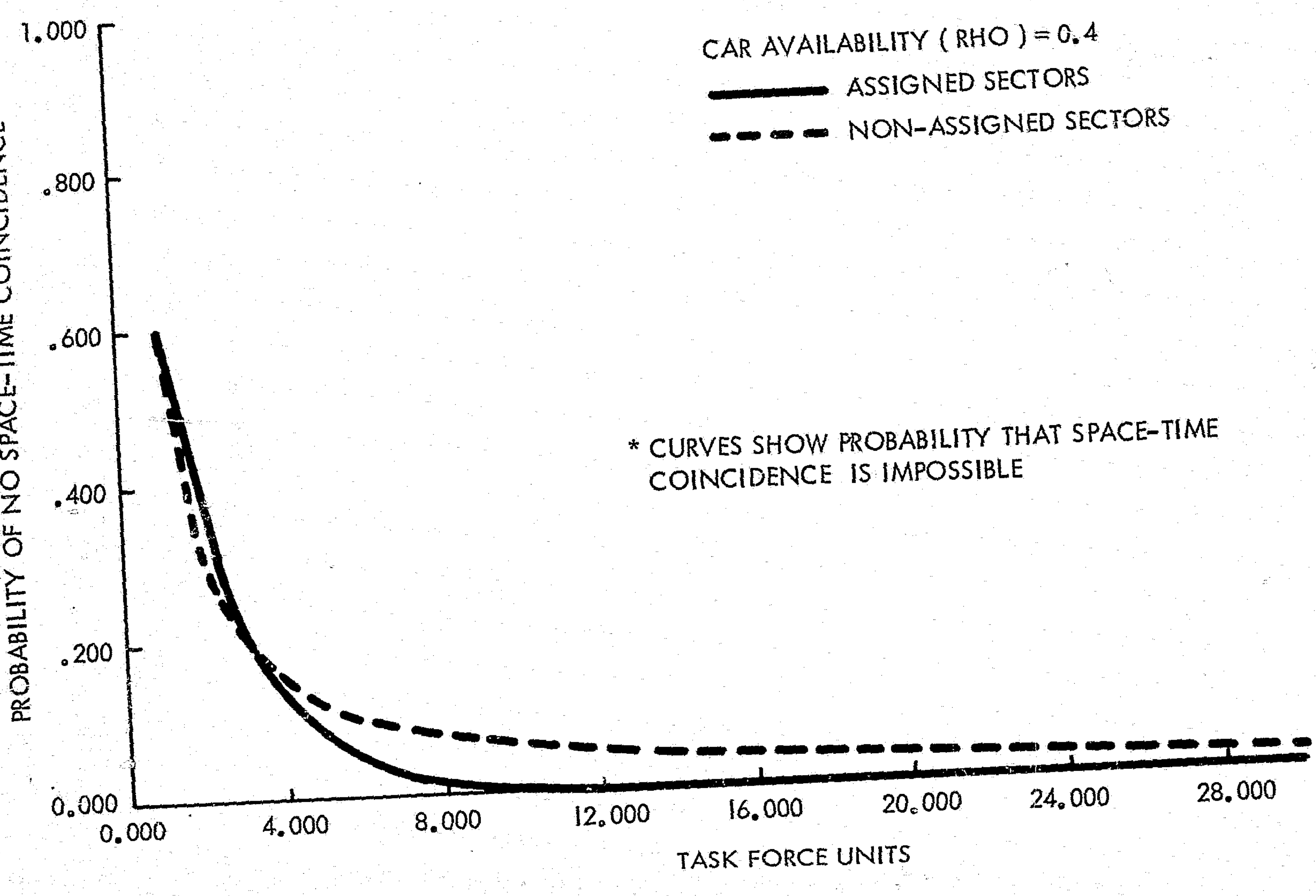
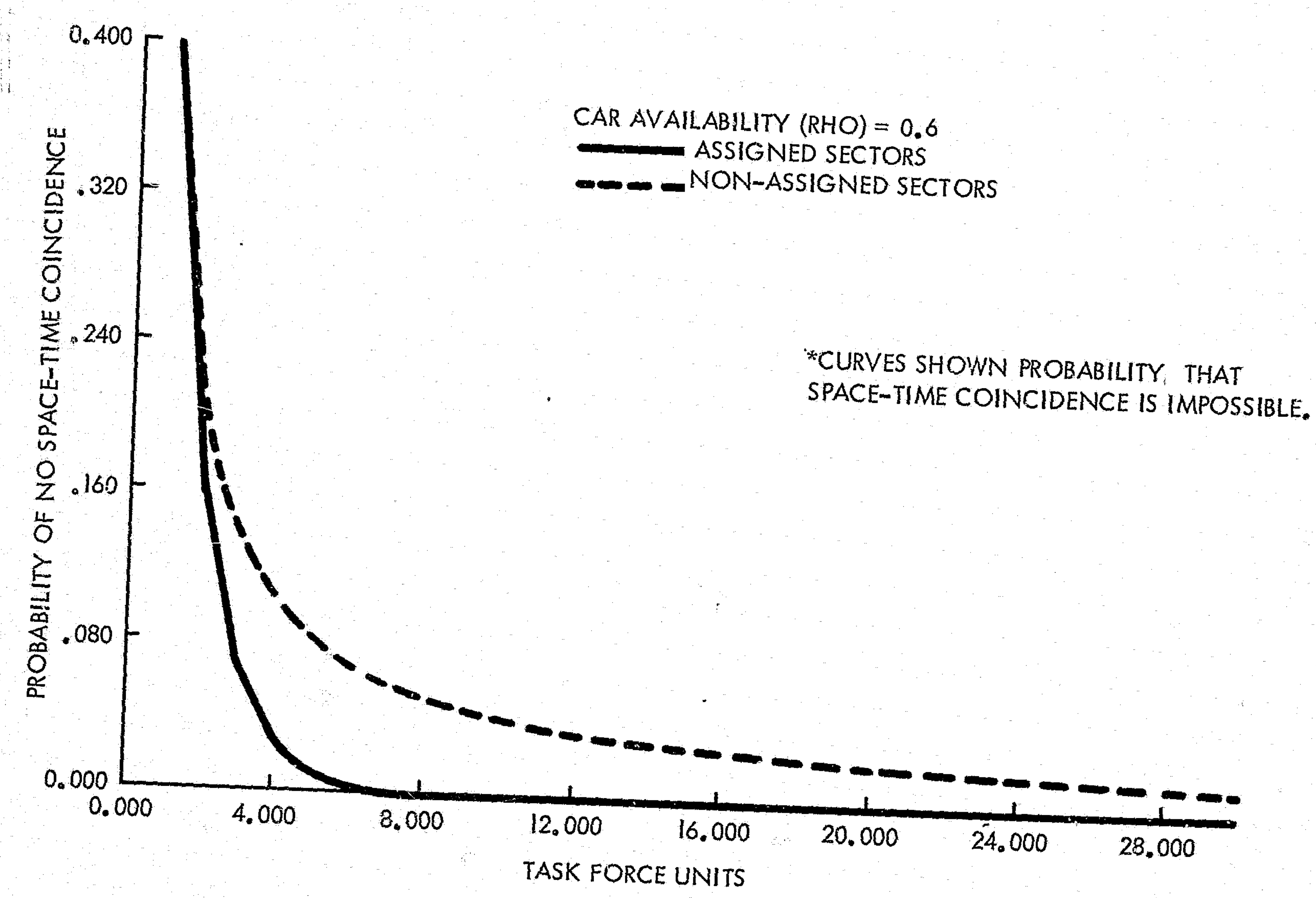


Figure 5-29: The probability of no space-time coincidence* as a function of task force availability for assigned sectors and non-assigned sectors



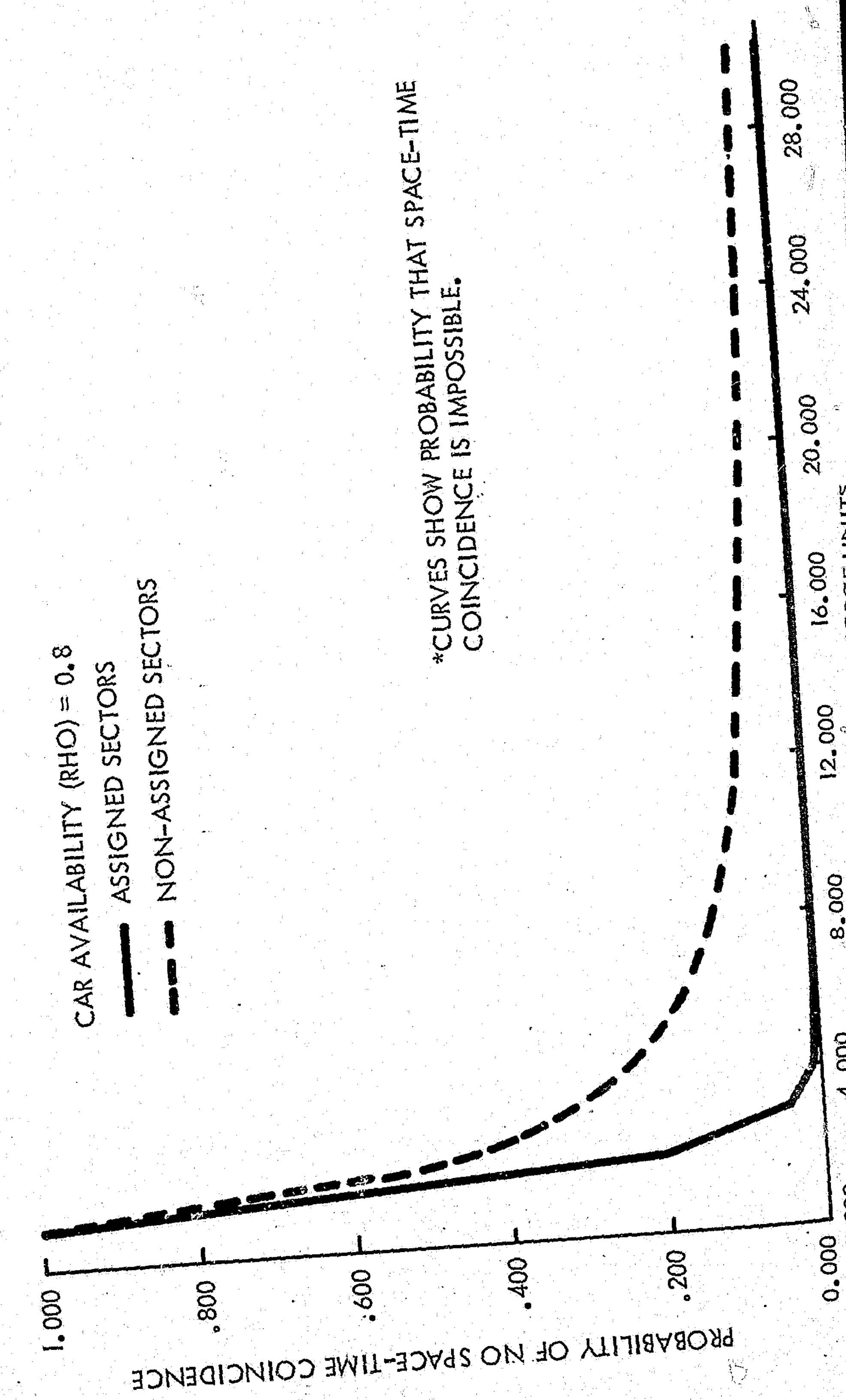


Figure 5-30:
THE PROBABILITY OF NO SPACE - TIME COINCIDENCE*
AS A FUNCTION OF TASK FORCE AVAILABILITY
FOR ASSIGNED SECTORS AND NON-ASSIGNED SECTORS

assigned sector method appears generally superior. This would not be true when equations (2) and (7) give widely different values for the same values of K, ρ, B, A, S and T. As a modification to the last set of equations, Elliott[10] used the average revisit time, T, and the time required to carry out the crime, plus the time that the perpetrator remains in the area and is identifiable, t, to estimate the probability of crime detection by random patrol. The probability in this case is written as

$$p = 1 - \exp(-t/T), \quad \frac{t}{T} < 1 \tag{10}$$

This formula is the same as the Blumstein-Larson[4] expression when

$$\frac{BA}{KS}$$

is regarded as the average revisit time, and the symbol T in this paper is given the same definition as t in Elliot's equation. Then

$$p = 1 - \exp(-T/(BA/KS)).$$
$$= 1 - \exp(-KST/BA). \tag{11}$$

Both Blumstein and Larson[4] and Elliot[10] use the same model, one which depends heavily upon a realistic estimate of the time to commit a robbery or the time that the criminal is identifiable. Elliot provides a set of curves for different values of t/T.

Figure 5-3 was computed from values of S, T, and BA that are typical of Task Force units operating in a particular high-crime area for the crime of a street robbery. This example is an extreme case, both from the standpoint of no difference between the assigned and non-assigned sector cases and the small values of space-time coincidence.

In the robbery example, an average time of 45 seconds was assumed for a robbery, and a patrol speed of 9.2 mph was used to estimate the coverage of one unit. This patrol speed was the mean of a distribution of patrol speeds recorded by Task Force units for a period of about one week. The total miles of streets and alleys for the two districts comprising A was measured as 242.9 miles. (While robberies do not occur as frequently in alleys as along streets, the units are also looking for burglaries, auto-stripping and other crimes; these require the patrol of alleys.) If the assumed time of the robbery were doubled, the probability of space-time coincidence for the assigned sector case would double. For Figure 5-3, the probability would increase from approximately 0.010 to 0.020. An even more dramatic increase would occur for the crime of burglary. If the patrol speed of 9.2 miles per hour were reduced by one-half to permit more careful examination of buildings for signs of forcible entry, and the assumed value of the time duration (T) were increased by a factor of 40 to 30 minutes, the probability would increase to 0.2 for a force of 20 men. The increases for the non-assigned sector case would be somewhat less.

These numerical examples show that patrol effectiveness as estimated by the probability of space-time coincidence is directly proportional (for the assigned-sector case) to T. Hence the estimated effectiveness is largely dependent upon the type of crime, since T varies with crime type. Another consideration for the robbery example is given next, the realistic estimation of T for robbery.

The time of 45 seconds for a robbery was based on estimates by police officers, but it represents only the time of confrontation between the robber and the victim. It does not necessarily represent the time of the criminal event which could alert a police officer to a possible crime. As an example, one Task Force unit spotted a suspicious person and began questioning him. During the conversation, the victim of a robbery appeared on the scene and identified the suspicious person as a robber. In another case, a running man spotted a Task Force car and abruptly changed direction, throwing an object (a wallet) away at the same time. The person was captured, placed in the car and driven back in the direction of flight. Patrol officers then observed a man talking to another police officer. When they stopped, the man on the street identified the individual in the squad car as the person who had just robbed him. In these cases, the 45-second estimate would underestimate the probability of space-time coincidence. The criminal event includes all actions and circumstances by which police can connect a criminal to a crime.

Experimental verification, most likely by derivation, of T for different types of crime would be useful. Both of the above examples were taken from on-view arrest reports by Task Force units deployed in the districts used in the simulation. The cases occurred within days of each other. Since the examples show post-crime behavior of the criminal as the viewable evidence of a criminal event, the estimated time of the criminal act is meaningless. If on-view arrest records recorded the time between arrest and the time of the criminal act (i.e. the moment of victim-robber confrontation), the effective time duration of criminal events could be estimated as a function of the crime type. This "effective" time duration, T, could then be used. It would reflect criminal behavior as well as confrontation time.

Estimation and Verification

The average number of space-time coincidences considering ρ and the occurrence of N criminal events in A can be written in an analytical form as

$$KST\,\rho\,N/BA \tag{12}$$

for the assigned sector case. The Probability of at least one space-time coincidence out of N criminal events in A is

$$1-\left(1-\rho\frac{KST}{BA}\right)^{N} \tag{13}$$

In a computer simulation, equation (12) is solved by computing the space-time probability for each criminal event as a function of available Task Force units and using the average value in place of $\frac{KSTN}{BA}$.

Introducing the probability, P, for a patrol unit detection given a space-time coincidence, the average number of police detections is written as

$$D=\frac{P\rho KSTN}{BA} \tag{14}$$

Verification of the model becomes a problem of data collection and the proper statistical interpretation of the data. The model is manpower-dependent, and it is supposed to estimate the probability of infrequent events. Because a model of patrol is needed to investigate tactics and to extimate the effectiveness of police patrol, an expenditure of effort to verify the model is warranted. To accomplish this, data should be collected which will provide the number of criminal events, the number of on-view arrests and the number of patrol units. The probability of attaining the actual number of on-view arrests with the estimated space-time coincidence probability from the model will be computed. If the computed space-time coincidence is too low to yield the number of actual arrests, the time T_R will be increased to determine if the curves can be fitted in this manner. In addition, the assumptions of truly random patrol and the distribution of robberies will be examined.

From historical data, the number of on-view arrests for a particular crime type by task Force units can be found. An on-view arrest represents both a space-time coincidence and a detection by police. This is written as

$$P_A=P(d,st) \tag{16}$$

(Implicit in this formulation is the assumption that the conditional probability of arrest, given patrol detection $(P(A/d))$, is unity. As stated before, this is not necessarily true, but the value is close to unity and the data to estimate $(P(A/d))$ is practically nonexistent. Therefore, it is neglected in the formulation.)

Using the definition of conditional probability,

$$P-P(d\mid st)=\frac{P(d,st)}{P_{st}} \tag{17}$$

Where P_{st} is the probability estimate of space-time coincidence as computed from the models in this section.

If there were n criminal events and m on-view arrests for that specific type of criminal event, the initial estimate of the probability of arrest, given a criminal event, is m/n. Out of n robberies, the probability of m arrests is given by the binomial distribution as

$$\frac{n!}{m!(n-m)!}P_A^{m}(1-P_A)^{(n-m)} \tag{18}$$

if the probability of arrest –, given a criminal event, is $P_A=P(d,st)$.

By this equation, as long as $0<P_A<1$, there is always a finite probability of m arrests, given n criminal events, regardless of the value of P_A. The problem is then to determine the best estimate of P_A and a range of acceptable values for P_A around this estimate. From the nature of the data, no single value of P_A will be obtained; instead there will be a range of "reasonable" values. A brief description of the approach is given by Blumstein and Larson.[4]

If n criminal events resulted in n on-view arrests, an initial estimate of the probability of arrest would be

$$P_A=m/n \tag{19}$$

The expected number of arrests out of 100 criminal events in a second sample of 100 would then be $100P_A$. The difference in the actual number of arrests and the expected number of arrests in this second sample set of 100 criminal events would be

$$|100P_A-m_1| \tag{20}$$

where m_1 is the actual number of arrests in the second set of 100 criminal events. If yet another set of 100 criminal events were selected, the agreement with the expected number of arrests would be equal to or worse if the number of arrests was equal to or greater than $100P_A+|100P_A-m_1|$, or if the arrests were equal to or less than $100P_A-|100P_A-m_1|$. In equation form, the result would be worse if

$$100P_A+|100P_A-m_1|\le m_2$$

or

$$|100P_A|-|100P_A-m_1|\ge m_2 \tag{21}$$

where m_2 is the number of arrests in the second set of 100 criminal events.

At this point, the use of the normal distribution to approximate the binomial should be discussed. The normal distribution approximation is introduced for later computation of the "reasonable" range of P_A. Tables exist for the normal distribution that permit an easier analytical representation of the distribution of estimates of P_A computed from different data sample sets.

The value of P_A will be quite small. As such, the sample size of the data used to estimate P_A should be large to reduce the error of the normal approximation. For values of P_A as small as 0.02, a sample size of 1000 is large enough. The examples given here use a sample size of 100, but this should be increased if the first estimate of P_A is small. The sample size as a function of P_A to obtain a close approximation of the normal to the binomial distribution is given in many standard statistical texts and will not be repeated here.

Approximating the actual distribution of arrests in the second sample set of criminal events with a normal distribution, the mean would become $100P_A$ with a standard deviation of

$$\sigma=(100P_A(1-P_A))^{1/2} \tag{22}$$

The probability that another sample set would show more disagreement than the first set is then given by the equation

$$\left(\frac{2}{\pi}\right)^{1/2}\int_{|m_1-100P_A|/\sigma}^{\infty}\exp(-\tfrac{1}{2}x^2)\,dx \tag{23}$$

Correct use of this equation is dependent upon the assumption that the normal distribution provides a close approximation to the binomial distribution. If this assumption is justified, the general use of this equation for this purpose can be written as

$$\left(\frac{2}{\pi}\right)^{1/2}\int_{|m-nP_A|/\sigma}^{\infty}\exp(-\tfrac{1}{2}x^2)\,dx \tag{24}$$

where

$$\sigma=(nP_A(1-P_A))^{1/2} \tag{25}$$

and m is the number of arrests out of n criminal events.

The "reasonable" limit is traditionally set at a value of 0.05. If there was no difference between the estimates of arrests and the actual number of arrests, the value of the integral would be unity. An estimate of P_A which gives a value of equation (23) greater than or equal to 0.975 is then considered reasonable. Values of P_A giving this result gives the range of values which can be accepted at the 5 percent confidence level for a two-tailed test given the null hypothesis.

The initial estimate of P_A can be obtained in several ways. The most straightforward is the number of arrests out of 100 criminal events. This can be tested in the manner described in the preceding paragraphs with other samples of 100 criminal events. Another estimate could be obtained by the computation of space-time coincidence. If this estimate fell within the "reasonable" range of an estimate of the probability of arrest, given a criminal event occurrence, the conditional probability of detection and apprehension is close to unity, given the assumptions of random patrol underlying the space-time coincidence.

If the probability of space-time coincidence is higher than the upper limit of a "reasonable" probability of arrest, then the probability of detection and apprehension, given a space-time coincidence, is significantly lower than unity. Finally, if $P_{st}<P_A$, either the values for T or S are incorrect or the entire formulation of the random patrol model is wrong. The first approach is to check the value of T to see if the results can be improved by increasing T. The examples of two on-view arrests for robbery in the earlier section show that the value of T could be easily underestimated.

To summarize, the probability of space-time coincidence, P_{st}, gives an upper boundary on the probability of arrest, if the models and the values in the models are nearly correct, as used to estimate P_{st}. The probability of arrest, P_A, and an estimate of the "reasonable" range of P_A can be obtained from historical police data. If P_A is less than P_A, the model or the values must be examined, since P_{st} should always be greater than P_A.

Since P_A will have a range of values, and a range of values can be computed for P_{st} by estimating ranges of the values for T and S, then a range for $P(d/st)$ can be estimated by the use of Monte Carlo techniques with a digital computer. Otherwise, the expected values of P_{st} and P_A can be used with equation (17) to estimate the expected value of $P(d/st)$. If this analysis shows $P(d/st)$ to be quite small, while a good deal of faith is placed in the values of P_{st} and P_A, a program of training or the design of different search procedures would seem necessary.

This verification procedure was not undertaken with Chicago data. The method is suggested, however, for test by other researchers.

Maximizing Space-Time Coincidence

In the mathematical development for computing the probability of space-time coincidence, both linear and exponential saturation laws were used. Here is described a mathematical method for allocating search effort to maximize the probability of space-time coincidence.

In this application, the probability of space-time coincidence is maximized. If this maximization occurs, the police units, if marked, will maximize their immediate deterrence effect, and they will minimize their response time to a crime-in-progress call while maximizing their opportunity to make an on-view arrest. The allocation of a limited amount of search effort was investigated by Koopman[11] a number of years ago. He offers a graphical means of solution. Charnes and Cooper[12] gave a mathematical programming solution to Koopman's problem, and this is used here to solve the allocation with a digital computer. Deployment of units against the street crime of robbery serves as the specific application.

Assuming an exponential-saturation law of space-time coincidence which corresponds to random patrol with non-assigned sectors and assuming further that the probabilities of a crime occurring during a certain time interval in a region of the city can be estimated, then the problem is to find the optimum manner of distributing the search effort. The search effort, in this case, is the total number of police units available for preventive patrol assignments.

In a more precise statement of the problem, the probability density $p(x)$ is given. The quantity $p(x)\,dx$ is the probability that the robbery will occur between x and $x+dx$.

$$p(x)\geq 0, \quad \int_{-\infty}^{\infty} p(x)\,dx=1 \qquad (26)$$

The amount of search between x and $x+dx$ is represented by a search density $Q(x)$ which has the properties

$$Q(x)\geq 0, \quad \int_{-\infty}^{\infty} Q(x)\,dx=\Phi \qquad (27)$$

Φ is a positive constant which is the measure of the total amount of search available. According to the exponential-saturation law, the conditional probability of a space-time coincidence given that a robbery occurs at x is $p(x)(1-\exp(-Q(x))\,dx$. Thus, the probability of space-time coincidence in the interval x to $x+dx$ is

$$p(x)(1-\exp(-Q(x)))\,dx \qquad (28)$$

The overall probability of space-time coincidence for the entire patrol region is

$$P=\int_{-\infty}^{\infty} p(x)[1-\exp(-Q(x)]\,dx \qquad (29)$$

The mathematical problem is to find the distribution of search effort function $Q(x)$ which maximizes P.

For the discrete case[12] the problem is to minimize

$$\sum_{j=1}^{n} h_j \exp(-\alpha Q_j)$$

Subject to

$$\sum_{j=1}^{n} Q_j=1, \quad Q_j\geq 0 \qquad (30)$$

where $\alpha>0$ is a constant relating the allocations, Q_j, of search effort to the total amount of search available. In this case

$$h_j\geq 0$$

$$\sum_{j=1}^{n} h_j=1 \qquad (31)$$

where h_j represents the relative frequency of criminal events in the jth rectangle to the total number of criminal events in all rectangular cells composing the search area. It is used as the known probability, replacing $p(x)\,dx$, that the target will be in area j.

(Use of rectangular areas is arbitrary, and the reasons for choosing them will become apparent. Occurrence of crime within each small rectangular cell is assumed uniform. The miles of streets and alleys for a cell is used with the patrol model to estimate the probability of space-time coincidence within a cell.)

So far the allocation problem has been discussed in very general notation. Here the expressions

$$1-\exp(-Q(x)),\ \Phi,\ Q_j, \text{ and } \alpha \qquad (32)$$

are replaced by

$$1-\exp\left(-\frac{KST}{BA}\right),\ U,\ \frac{K_j}{U}, \text{ and } \frac{UST_r}{BA} \qquad (33)$$

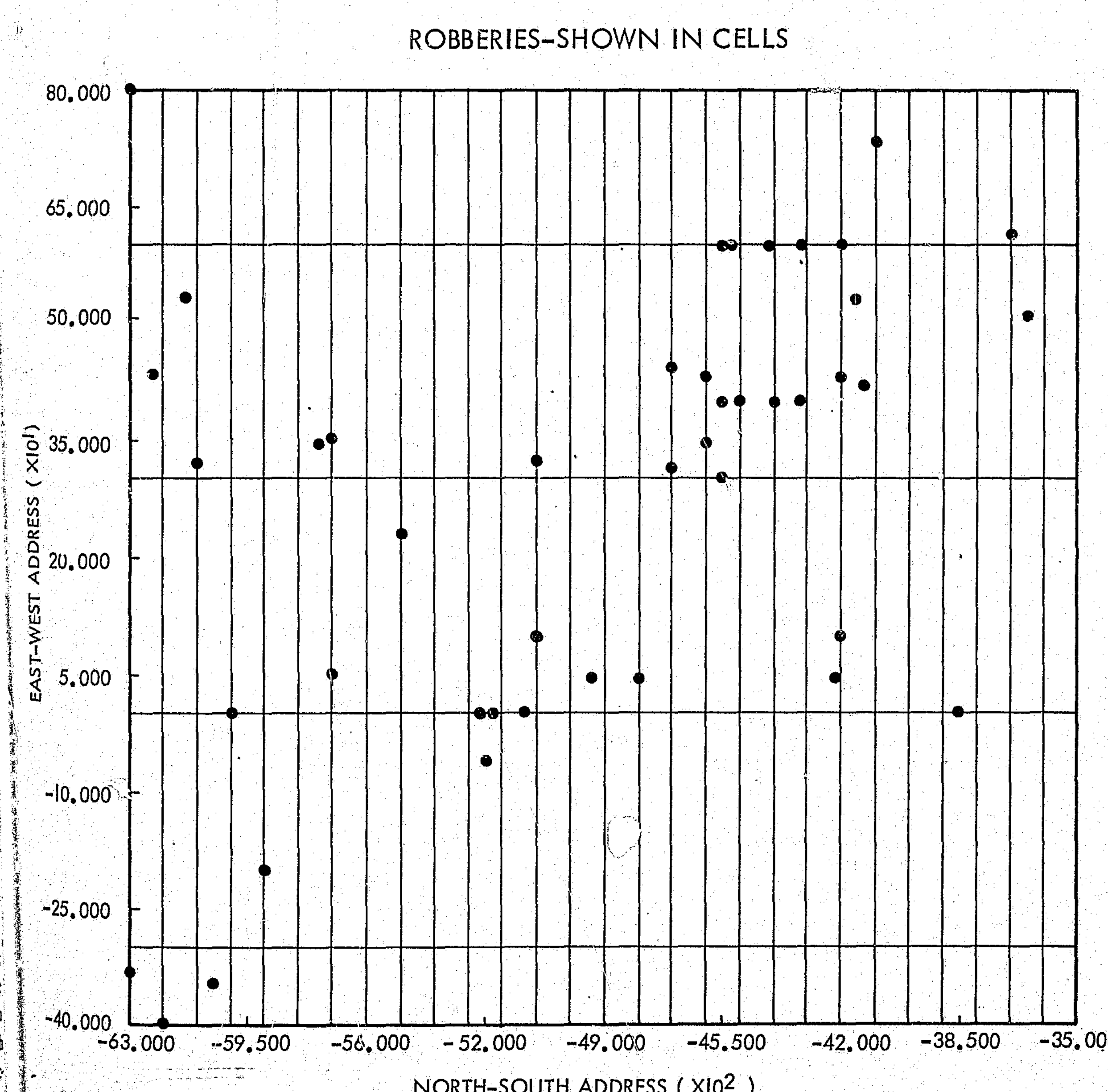
U represents the total number of patrol units available.

The models for space-time coincidence and the allocation of search effort were combined with actual robbery data from different regions of Chicago. The goal was to maximize space-time coincidence between a police unit and a robbery event. Allocation of search effort assumed that the probability of a robbery occurring in a particular region was given. In reducing the approach to a practice, robbery data was analyzed for clustering in space and in time for estimating the probability of a robbery in a particular region.

The following analysis yields the conditional probability that, given a robbery in a section of the city, the robbery will occur in a smaller subsection. This is not the same as estimating the actual probability that a robbery will occur in the subsection. A computer program, CELCOUNT,[13] had been developed by the geography department of Northwestern University, and it was modified to estimate the conditional probability of a robbery. The program uses specified increments of the x and y directions to divide a region into rectangular cells having the dimensions AX by AY. The program then counts the data points which fall within each AX by AY cell. The program outputs the percentage of cells that have one, two, three, etc. data points. For analyzing the robbery problem, several modifications were made to CELCOUNT.

The Chicago address system of numbering streets in both the North-South and East-West directions made these modifications and subsequent applications easy. An address such as 525 N. Michigan Ave. was

Figure 5-31: 2nd District June 7 – June 13, 1969 48 Robberies

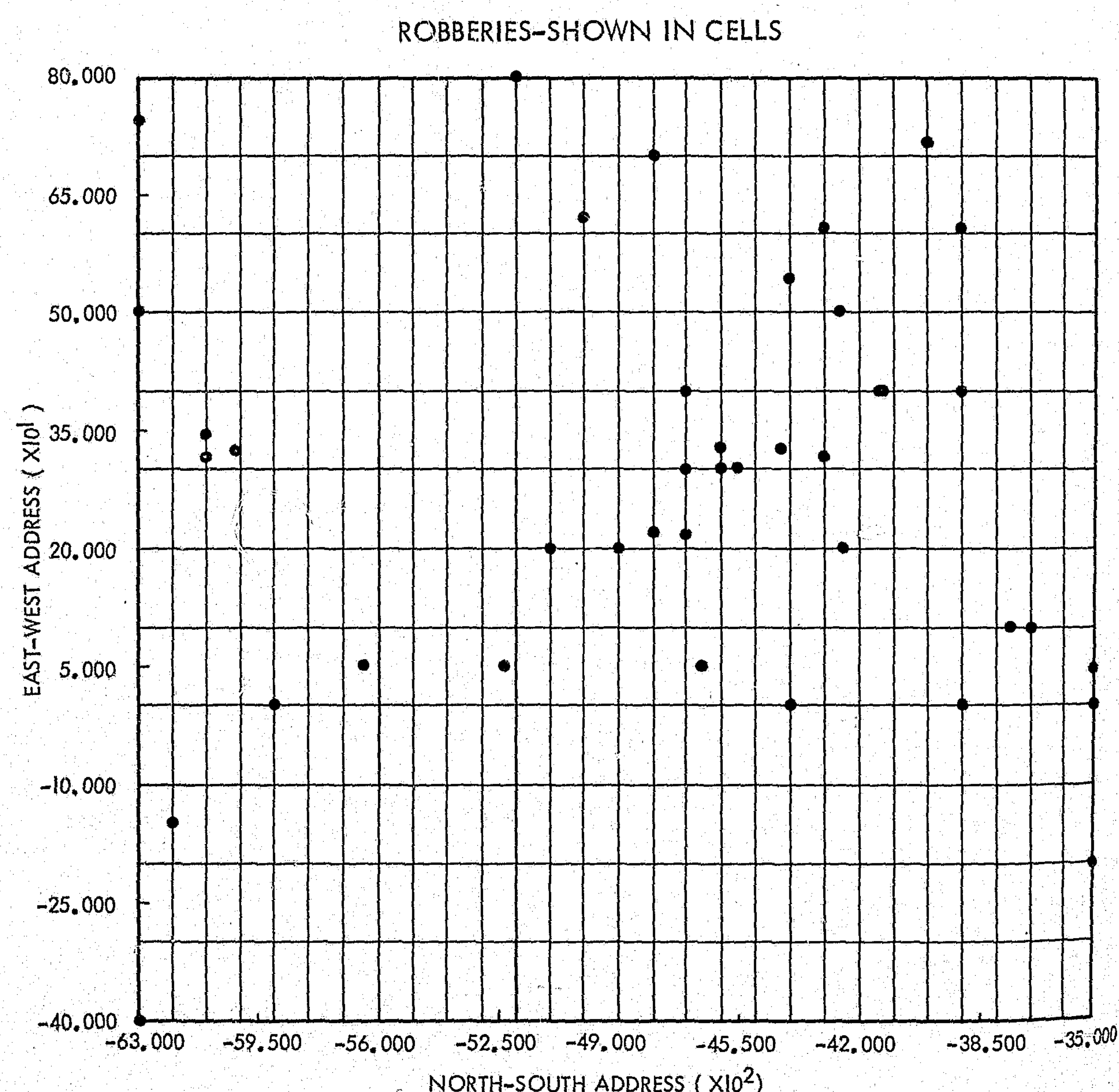


coded as 525 North by 100 East. All streets have a numerical designation in the Chicago Street Guide. In addition, an increment of 800 in address numbers represents a mile with only a few well-defined exceptions. Madison Street and State Street divide the city into North-South and East-West sections, respectively. In the program, Quadrant-1 is the northwest section, Quadrant-2 is the southwest section, Quadrant-3 is the northeast section and Quadrant-4 is the southeast.

All calls to the police department that require the dispatching of a police unit have the quadrant number and the numbers representing the north-south and East-West coordinates of the complainant's address. These are given in addition to the time of occurrence, type of call and other information. Cards for robbery calls were obtained daily. Boundaries of several high crime areas of the city (each representing about 4–5 square miles) as well as the time periods of 1000–1800 and 1800–2000 hours were specified in the computer program. Robbery data meeting these qualifications were then used in CELCOUNT.

Originally, CELCOUNT used floating point data. For the study, fixed-point arithmetic was used because many of the data points fall on boundaries (streets) of the cells, and round-off errors would result in an assignment to only one cell. Also the original program

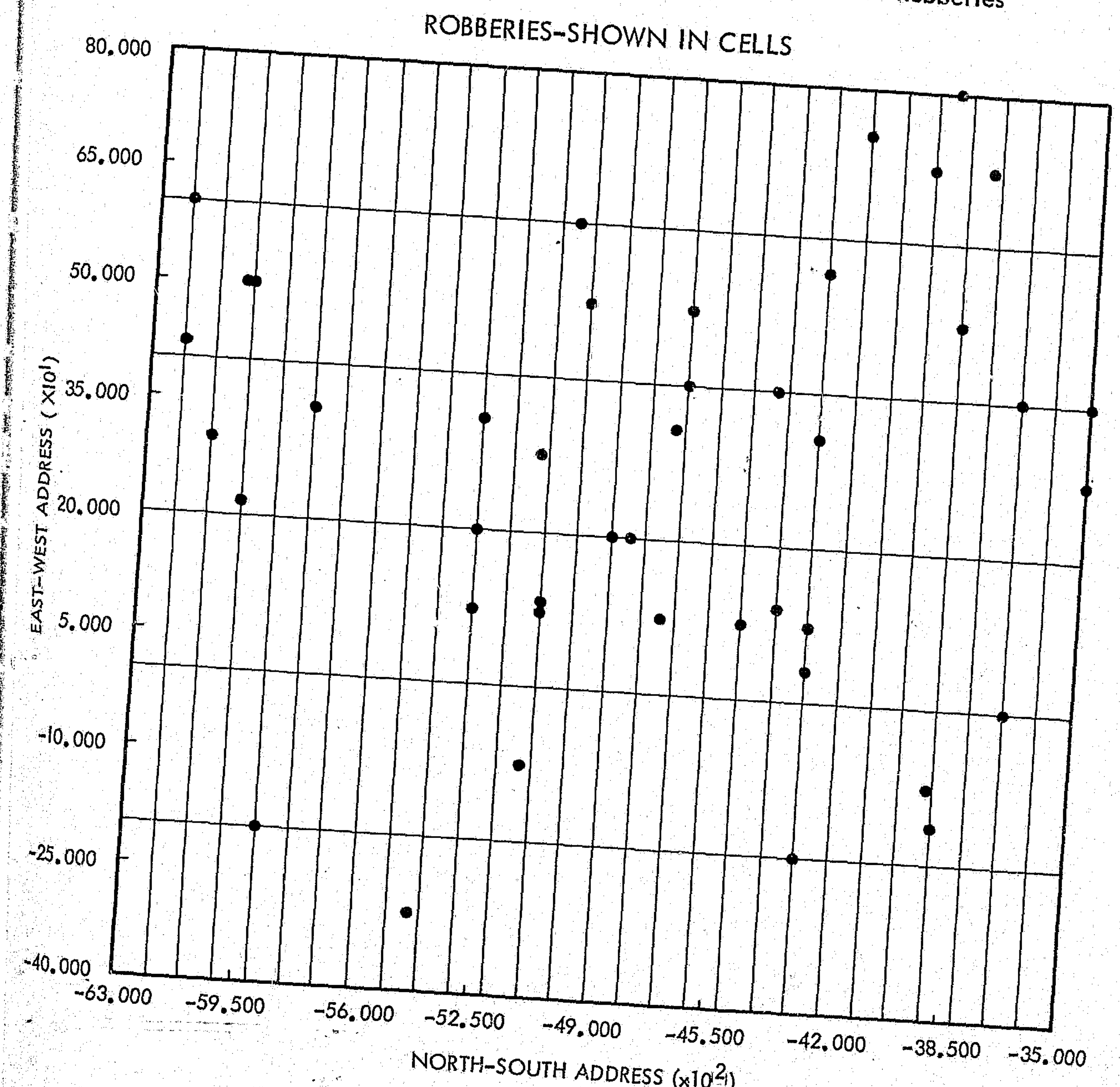
Figure 5-32: 2nd District June 21 – June 27, 1969 46 Robberies



would assign a point on a boundary to only one cell. The subroutine CELCOUNT was changed to assign boundary data points to both cells. To use CELCOUNT for assignment purposes, each cell was identified and the actual number of robberies for each cell was maintained in an array. This number was divided by the total number of robberies (This total increased if a robbery was assigned to more than one cell), and this fraction was used as the estimate of the probability that a robbery would occur in that particular cell. These totals represented three weeks of robbery data. The data was updated by dropping the oldest week of data, adding the most recent week.

Once the probabilities (conditional) of a robbery occurring in a particular cell were computed, the cells were ranked in decreasing order of probability, and the natural logarithms of the probabilities were taken. The number of cells for search by police units and the fraction of police units out of the total number were then calculated, using equations (30) and (31) in the section on search allocation. Each cell size has a different value for the number of miles of streets

Figure 5-33: 2nd District July 19 – July 25, 1969 45 Robberies



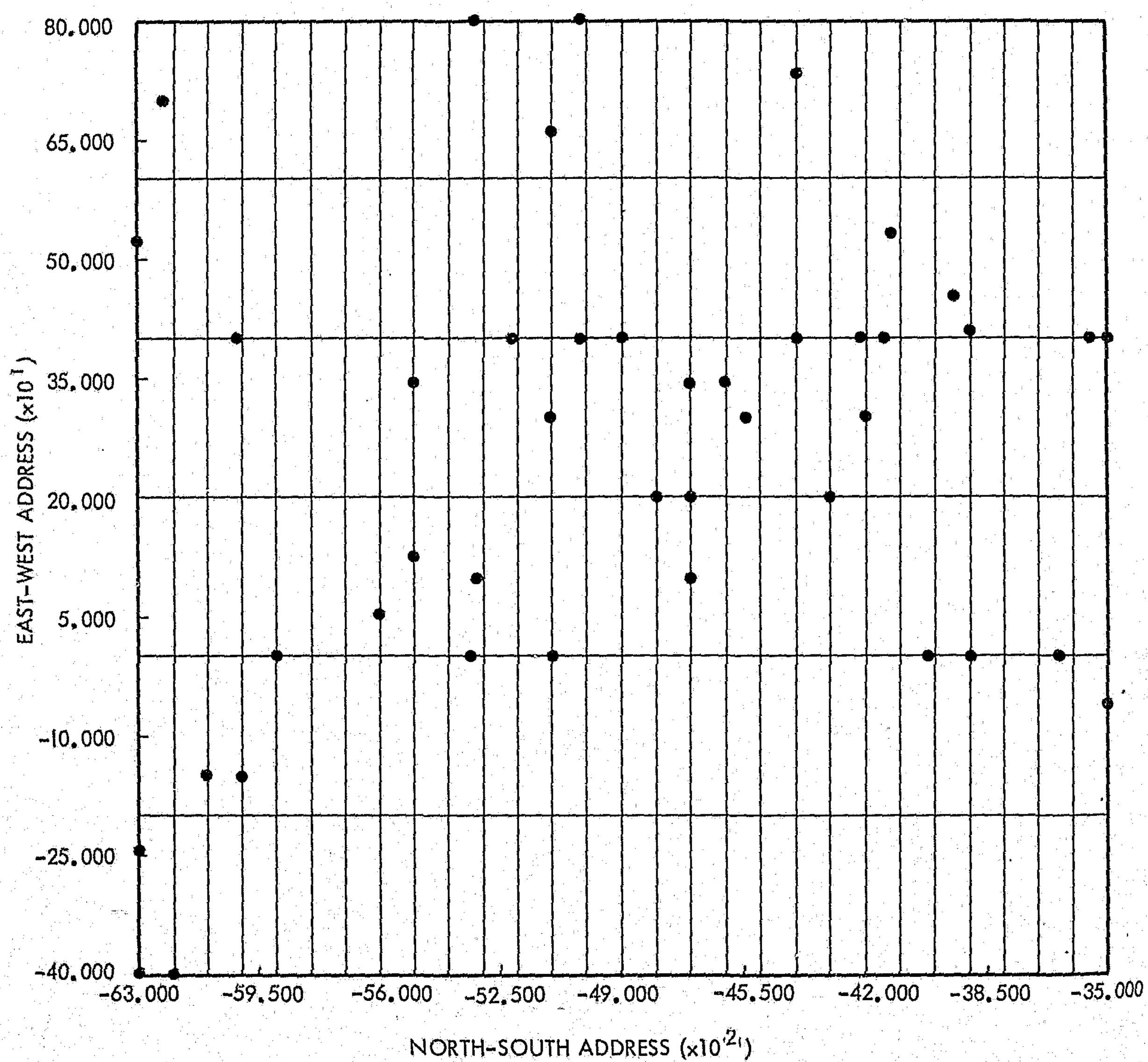
and alleys. Since the overall probability of space-time coincidence depends on this value, an iterative method of varying the cell size was used to maximize the overall probability of space-time coincidence in the high crime area. Values of AX and AY were varied as 100, 200, 300 and 400. This gave 16 different cells varying in size from 1/64th to 1/4th square miles.

Quite frequently, an increment in street address of 100 corresponded to one city block, but in many areas of the city there are half-blocks. As such, the values for the number of miles of streets and alleys for a given cell size is not necessarily constant throughout the city. Constant values, however, were used in this program. Sixteen different values were used since half-blocks occur more frequently in one direction than another. Hence the values would differ for a cell 100-x-200 and one 200-x-100, even though the area was the same.

The probability of achieving a space-time coincidence for all 16 cell sizes was computed by multiplying the probability of space-time coincidence, given a robbery in the cell by the conditional probability of a robbery occurring in that cell, and summing over all cells which had units assigned. The maximum probability was used, and the assignment were made with the corresponding cell sizes and cell locations.

Figure 5-34: 2nd District July 26- August 1, 1969 46 Robberies

ROBBERIES - SHOWN IN CELLS



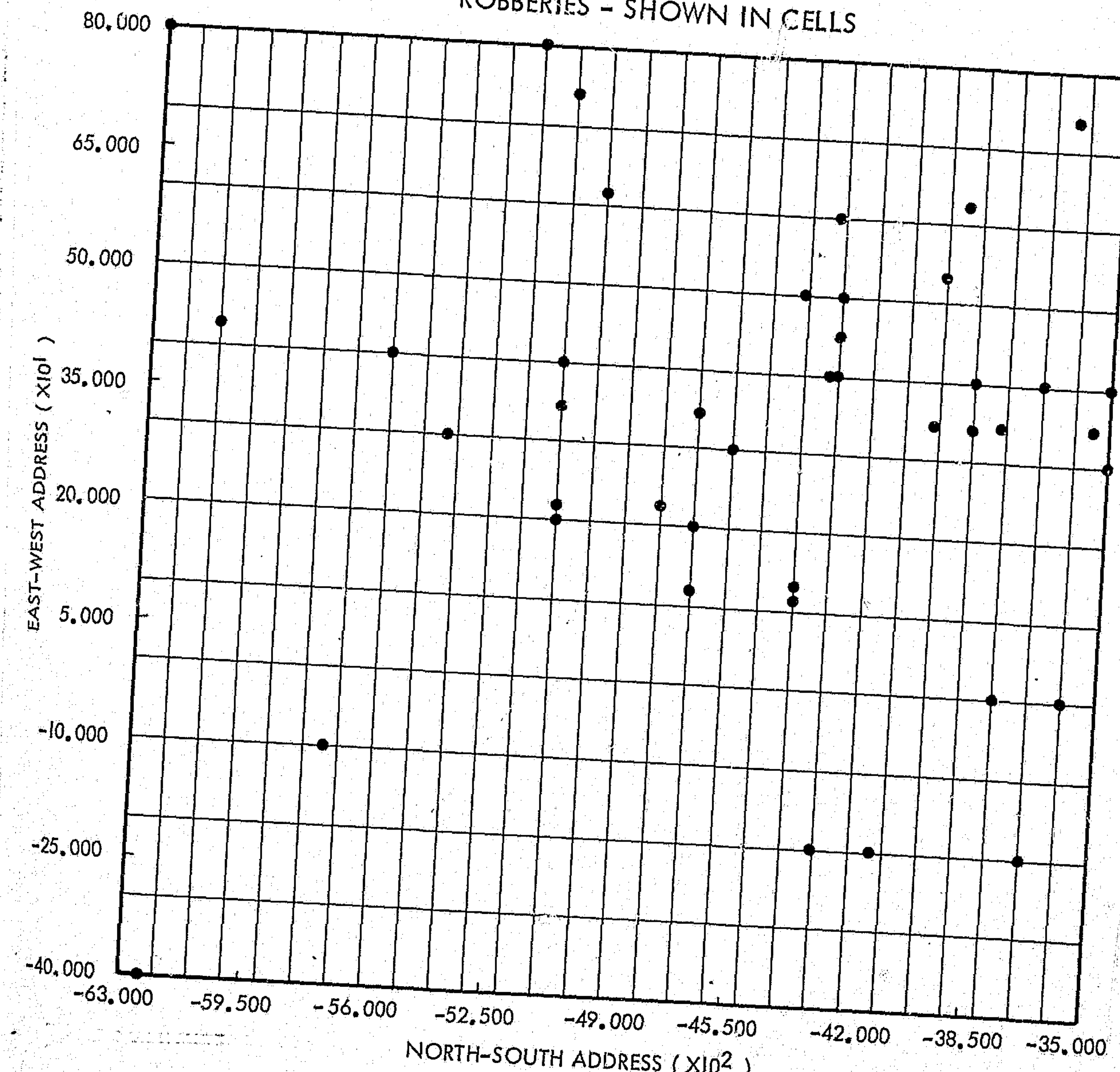
To identify the geographic regions for patrol, the computer program used a CALCOMP plotter to draw the locations of all robberies in the data on a grid of the cell size which produced the maximum space-time probability. This grid output is shown in Figures 5-31 through 5-35.

In this manner, the program sorted citywide robbery data by location and time, estimated the probability of a robbery occurring in a particular cell, assigned cells for patrol, determined the fraction of available patrol units for patrol in each cell and calculated the overall probability of a space-time coincidence. This was done for 16 different cell sizes. The cell size yielding the greatest overall probability of space-time coincidence was used for the selection of the assignments of patrol units.

Full evaluation of the assignment program has not been completed. It was intended to modify the Task Force simulation to include geographic characteristics of each unit. Actual robbery data would have been introduced as an exogenous event, and the probability of space-time coincidence would have been computed on the basis of the number of Task Force units in patrol status in a geographic area where the robbery occurred. The stochastic simulation was extended, and robbery data was collected from 9 January 1969

Figure 5-35: 2nd District August 2 - August 8, 1969 43 Robberies

ROBBERIES - SHOWN IN CELLS



through the end of the study period. In addition, the cell count data for 100-x-10 cell sizes was punched to be used in a simple Chi-square test to determine if the crime distributions changed from one period to the other. Lack of time prevented an evaluation based on a calculated maximum probability of space-time coincidence over the robbery data time period. This evaluation would check the accuracy of robbery probability forecasts and whether the Koopman allocation method significantly increases the probability of space-time coincidence over current assignment methods.

The final phase of evaluation would include a field test. One of the basic assumptions in using the Koopman allocation method is lack of knowledge by the opposing forces of the search deployment or an unwillingness to change their mode of operation in light of the search deployment. The reaction time of the criminal population to a change in police deployment is unknown. While the crimes of robbery are largely opportunistic and unrelated to each other in the high crime areas, a significant number of potential robbers might rapidly perceive a shift in police patrol strength and concentrate their collective efforts in regions of minimal patrol strength. For this reason, the Koopman method might not apply to Chicago street crimes. If

Table 5–19

Comparative Probabilities for Space-Time Concidence Using Differing Cell Sizes in a Region. Calculations Based on Search Force of 20 Units, With No Allowance Made for Down-Time (District 2)
[Time period May 15–June 4]

Cell size	1000–1800 hours		1800–0200 hours	
	Number for search	Probability	Number for search	Probability
100 × 100	* 8	.0207	† 4	† .0261
100 × 200	5	.0181	2	.0265
100 × 300	2	.0173	2	.0173
100 × 400	4	† .0118	1	.0163
200 × 100	5	.0153	3	.0212
200 × 200	2	.0126	2	.0168
200 × 300	1	.0128	2	.0146
200 × 400	2	.0106	1	.0118
300 × 100	3	.0131	2	.0193
300 × 200	4	.0109	1	.0168
300 × 300	2	.0117	1	.0156
300 × 400	5	.0086	1	.0112
400 × 100	* 4	.0125	3	.0160
400 × 200	1	.0117	1	.0120
400 × 300	1	.0110	1	.0127
400 × 400	1	.0088	1	.0079

* More areas selected for search than used for actual assignment and calculation of the probability.

† Probability calculated using fewer units than were actually available, due to round-off error.

Table 5–20

Comparative Probabilities for Space-Time Coincidence Using Differing Cell Sizes in a Region. Calculations Based on Available Search Force of 20 Units, With No Allowance for Down-Time (District 18)
[Time period May 1–21]

Cell size	1000–1800 hours		1800–0200 hours	
	Number for search	Probability	Number for search	Probability
100 × 100	4	.0404	3	† .0426
100 × 200	4	† .0335	* 3	.0392
100 × 300	4	.0303	1	.0374
100 × 400	4	.0198	1	.0353
200 × 100	* 3	.0267	2	.0376
200 × 200	2	.0185	2	.0301
200 × 300	2	.0229	1	.0330
200 × 400	4	.0133	1	.0288
300 × 100	* 1	.0230	* 2	.0282
300 × 200	2	.0168	4	† .0217
300 × 500	1	.0211	2	.0272
300 × 400	3	.0127	1	.0223
400 × 100	2	.0193	2	.0304
400 × 200	4	.0143	1	.0233
400 × 300	1	.0226	1	.0262
400 × 400	1	.0126	1	.0199

* More areas selected for search than used for actual assignment and calculation of the probability.

† Probability calculated using fewer units than were actually available, due to round-off error.

the robbers in some collective sense have good knowledge of police deployment, some other allocation method should be used. Perhaps this deployment might be based on game theory or on a rapid updating of robbery data to predict the next regions of clustering.

In addition to a street test of the forecast for robbery clustering, and any resultant criminal response, a test of the Blumstein-Larson patrol model is necessary also. This would require a comparison of actual on-view arrest data to a theoretical computation of space-time coincidence. This data is available, but insufficient time existed to check the patrol model. The Koopman allocation linked to the Blumstein-Larson model of patrol produced large numbers of patrol forces assigned to rather small cells. Since on-view arrests are quite rare and the density of patrol forces in these areas is already quite high, the results could be correct for these high-crime regions. Many of the captured robbers have previous criminal records, and the monetary gains from each robbery are often quite small. This would seem to indicate that the deterrent effects on the criminal population in these areas are minor.

ROBASIN, the program described here, was run for several sections of the city. The computer results

for several areas covering the time periods of 1000–1800 hours and 1800–2000 hours demonstrate the clustering of robbery events and the order-of-magnitude increase in the theoretical value of the probability of space-time coincidence under the Koopman allocation method.

The assignments of manpower were made by multiplying the fraction of search effort assigned by the computer program times the number of Task Force units available. In a few instances the estimated probabilities of robbery occurrence were such that the program selected a large number of cells for search with a very small fraction of search effort assigned to each cell. As a result, only a fraction of a man was assigned to a cell. The program assigns only whole numbers of men to a cell, so not all of the cells selected for search received a man. Also, cells sometimes received several men plus a small fraction. Since the number was rounded off, a few instances occurred where fewer than the available units were assigned. Actually, fractions of manpower could be assigned to cells since they would spend only a fraction of their eight-hour watch in a particular cell. This would have the benefit of making the deployment more random to the potential criminal observer. This type of deployment will be investigated, but it assumed a uniform distribution in time of crimes over the

Table 5–21

Comparative Probabilities for Space-Time Coincidence Using Differing Cell Sizes in a Region. Calculations Based on Search Force of 20 Units, With No Allowance for Down-Time (District 18)
[Time period May 14–June 4]

Cell size	1000–1800 hours		1800–0200 hours	
	Number for search	Probability	Number for search	Probability
100 × 100	3	.0397	8	.0311
100 × 200	3	.0515	5	.0326
100 × 300	1	.0420	3	.0235
100 × 400	1	.0343	2	.0272
200 × 100	3	.0314	3	.0290
200 × 200	1	.0338	* 3	.0247
200 × 300	1	.0338	1	.0219
200 × 400	1	.0250	1	.0251
300 × 100	2	.0279	* 2	.0235
300 × 200	1	.0325	2	.0214
300 × 300	1	.0329	2	.0201
300 × 400	1	.0225	2	.0192
400 × 100	2	.0246	3	.0264
400 × 200	1	.0236	2	.0232
400 × 300	1	.0283	1	.0206
400 × 400	1	.0167	1	.0219

* Means more areas selected for search than used for actual assignment and calculation of probability.

Table 5–22

Comparative Probabilities for Space-Time Coincidence Using Differing Cell Sizes in a Region. Calculations Based on Search Force of 20 Units, With No Allowance for Down-Time (District 11)

Cell size	Time period 1000–1800 hours			
	Number for search	Probability	Number for search	Probability
100 × 100	4	.0245	5	.0212
100 × 200	6	.0238	4	† .0195
100 × 300	* 3	.0143	2	.0119
100 × 400	3	† .0170	3	.0136
200 × 100	5	.0175	4	.0169
200 × 200	2	.0147	2	.0127
200 × 300	2	.0114	1	.0122
200 × 400	1	.0142	1	.0117
300 × 100	2	.0155	5	.0109
300 × 200	4	.0114	1	.0105
300 × 300	5	.0091	2	.0088
300 × 400	2	.0107	1	.0090
400 × 100	2	.0135	2	.0129
400 × 200	5	.0091	1	.0097
400 × 300	5	.0070	1	.0090
400 × 400	1	.0082	2	.0082

* More areas selected for search than used for actual assignment and calculation of the probability.

† Probability calculated using fewer units than were actually available, due to round-off error.

eight-hour watch. Probably this is not true, but it could be accommodated.

The problems with round-off were quite infrequent, and the results show dramatically that crime, even in high crime areas, will cluster in space. Even within the 16 different cell sizes, a ten-fold increase in space-time coincidence was achieved. The probabilities show a sizeable increase over the results obtained from the simulation which assumed a uniform distribution of crime and the preventive patrol units. (See Tables 5-19 through 5-22)

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CHAPTER 6

DEMONSTRATION EXPERIMENT IN RESOURCE ALLOCATION*

The culmination of the Operations Research Task Force effort came in the demonstration of the split-force concept in District Fourteen. Basically, this was an experiment in administration that produced changes in the street operations of the police. Other demonstrations were carried out, including those related to robbery (District Two), burglary (Police Area Six) and, in the same area, auto theft and the Blue Fence power tactic. Improved procedures for command and control of police resources under emergency conditions were evolved through the help of the Communications Center personnel; these procedures were put into practice at the time of the Democratic National Convention in August of 1968.

Demonstration is an essential step of a project such as this one, involving the creation of a split-force for response and preventive patrol. Demonstration is also a difficult step, moving from suggested practices derived from analytical methods to production or operational implementation. This can be accomplished only through detailed staff planning. Preparation of an operation order is the same process, whether in a major city police department or in the military. The difference lies in the degree of adequacy in staffing; in law enforcement agencies the staff component is either non-existent or, at best, seriously undermanned. Chicago's police department is no exception.

Preparing operational plans and coordinating them through the Police department's command structure fell to police members of the Operational Research Task Force. Under the overall direction of Capt. James P. Moss, implementation of the District Fourteen experiment was carried out by Sgt. Robert Wagner of the ORTF. The steps are instructive for those contemplating future demonstrations and street experiments.

First, Sgt. Wagner forecast the expected calls for service for each of the police periods that arrived during June, July and August of 1969. He based this forecast on a linear extrapolation method developed by the project director. This method added a percentage increase for 1969 calls for service to the observed summer season of 1968 receipts of calls for service. Hourly distribution was estimated from historical records. In the event, the method proved accurate, within a few calls, at 300 per day.

Next Capt. Moss and Lt. Berry developed a "basic beat" map for the district. (In the process, they also developed a basic beat configuration for the entire city and showed a reduction of about 70 motorized beats.) The basic beat was a square whose diagonal represented a five-minute travel time under representative conditions. Capt. Moss and Lt. Berry prepared the beat structure from Chicago Transit Authority bus schedules and from their own knowledge of the city. Topographic features produced some compromise of the basic beat's square shape.

From this basic beat structure, Sgt. Wagner developed *recommendations* for assignment of patrol units to the response function and to the preventive patrol function. The concept of the basic beat included reinforcement of areas that require most police activity. Throughout the demonstration period, the preventive patrol function was the responsibility of the district's Crime Coordinator. This assignment was based on the district's crime activity, reflected on pin maps showing burglary, auto theft and crimes against persons.

In the next step, procedures in the Communications Center were modified so that the relay system could accommodate both the experimental designation and the normal motorized beats. Other modifi-

*Principal authors: A. M. Bottoms, Sgt. R. W. Wagner of the Chicago Police Department and Dr. Charles W. N. Thompson, Northwestern University. The differing observational points of view show up most clearly in this chapter in the commentary by the first two authors, "inside" the experiment and the "outside" comment by Dr. Thompson. The separate analytical efforts also reflect the professional disciplines (police officer and academician) and the boundaries of the experiment as seen by each viewer.

cations included the development of procedures for stacking and deferring non-emergency calls for police service.

Now representatives of the ORTF briefed District Fourteen personnel on the scope and objectives of the demonstration. Throughout the demonstration period, review sessions with district personnel were conducted by the ORTF. A professional evaluation of the experiment, called an "administrative experiment," was carried out by Fundamental Systems, Inc. of Evanston, Ill., under a subcontract to the Chicago Police Department.

The procedure, modification and concepts of the demonstration are feasible in the Chicago Police Department. The assumptions and analytical bases are sound. Given the various implied criteria for operations, these results were obtained:

(•) Although a 30-second increase in average response time to emergency calls was recorded, this was not deemed significant even though the average response time remained below five minutes.

(•) Deferral and stacking of non-emergency calls to increase police availability was shown to be feasible and acceptable to the community.

(•) Scheduling of units to the response function was flexible, and there were no reports of outage during the demonstration period.

(•) Results from the preventive patrol function were disappointing because there was little discernable increase in filing arrests or reducing the reported felonies; however, an increase of about 100 per cent in the actual effort applied to preventive patrol was seen. This increase was even greater during times associated with high crime, and this result underscores the conclusion that major effort should be devoted to crime-specific preventive patrol. (A similar experience was reported by St. Louis.)

(•) An increase in police morale was an unexpected result, occasioned by giving patrol officers more responsibility to make operational decisions. Participating officers received the experimental procedures well. This may be thought of as an experiment in team policing, and a significant contribution of team policing procedures may be the restoration of morale and initiative to operating level personnel by increasing their own perception of responsibility.

The result was the creation of a Strategic Patrol Force, using police units made available by reducing the demand for police service during specific time periods. Although the primary goal of the federally-funded grant program was the study of problems facing the large municipal police department, the results and methods are applicable to any size police agency. However the most important contribution is not readily visible. Meetings and dialogues between academicians and police officials resulted in outstanding displays of cooperative effort toward sharing the information and knowledge in each field. The implementation of the Administrative Experiment in District Fourteen (Shakespeare area) is an example of the blending of various disciplines and separate studies into a flexible patrol operations design.

In the technical division, found later on in this chapter, the experiment will be discussed as:

1. A simple mathematical prediction model of calls for police service.
2. The utilization of queuing and probability theory formulae to determine the level of police response service.
3. A design of a static geographical beat structure based upon distance traveled in a limited time.
4. The evaluation of increased amounts of strategic patrol.

Failure to continue the Operations Research Task Force prevented capitalizing on the lessons of the demonstration and denied the opportunity of acquainting the command echelons of the department with the operational potential of methods developed by the project.

BACKGROUND: STRATEGIC PATROL

The police administrator has one basic problem: How to best utilize the primary police resource, manpower. Crime and public service, as two separate and distinct functions, require particular skills and knowledge on the part of those involved. The police administrator must create an organization that will maximize the contribution of each department member.

Crime and public service are the responsibility of the patrol force since the beat patrol officer in his daily contact with the citizen creates the image of the department, determines the effectiveness of department policy and establishes the environment between the department and the citizen. The efficiency of the beat officer and the entire police agency depends upon those activities he is required to perform, what organizational restrictions are imposed upon him, and what information is available to him and the police administrator. Each of these problem areas was considered in the planning for the experiment.

The diversity of police activity was illustrated in the development of the Resource Analysis Budget for the Chicago Police Department. Structuring of the Resource Analysis Budget system resulted in a clear identification of the functional objectives of the police department. Concurrent analysis of the beat officer's activity revealed that many tasks performed are in fact of a service nature. The 1969 Department Program Budget indicates that approximately 75 percent *of the total* budget will be expended for *other than direct crime prevention activity*.

Subsequently, attention focused on the radio assignment of the beat officer. Acknowledging the reactive posture of the department, studies were made of the frequency of calls for police service as a whole, rather than concentrating upon the structured information categories of the Uniform Crime Report. Emphasis was placed on the assumption that an assignment of the beat officer will "cost" the police department the services of that officer for a period of time during which he is unable to perform the patrol function, i.e., he is not available to apprehend the criminal nor is he "visible" to the potential criminal as a deterrent.

Any program, therefore, must take into account of the number of calls for police service and must consider the amount of time he can be freed from the restriction of the radio to perform patrol.

Fortunately, the data bank of the Chicago Police Department is structured on the premise that the calls for police service are an integral part of the planning for manpower distribution. These data are maintained by time and geographic location to create reporting beats and to allocate manpower over the 24-hour police day. Additional information regarding multiple arrests, and incidents of resisting arrest and other assaults on police officers are correlated with the calls for service to determine the manning strength of specific beat vehicles.

Analysis of the data bank included a study of the information compiled for use in creating the reporting "patrol beat" structure. Current practice is based upon the weighting of crimes and calls for police service in order to arrive at a "balanced" workload for a particular beat. The weighting effect is evident only in the size of a beat, an inverse relationship. The greater the number of calls for service, the smaller the beat. Under analysis, the system indicates that although the "seriousness" of a crime receives compensation with a higher numerical weight, the tabulation of all reported incidents eliminates the bias. As a result, an area with few calls for service other than major crimes will have the same attention as an area with a large number of calls for service of a minor nature. The discrepancy is obvious: How much effort and time is needed to handle one Part I (weight 4) incident versus four miscellaneous incidents (each weighted 1); or a Part II incident (each weighted 3) versus three miscellaneous calls for service.

The relationships between police activity and police information must be analyzed to a far greater depth than currently exists in practice. Numbers alone cannot determine the most effective use of police manpower. Assigning a police officer to a beat consisting of two square blocks in an urban area can be an enormous waste of manpower if the officer is assigned because of a number of crimes over which he has no control. A beat officer in a vehicle on the street cannot offer effective deterrence to a burglary in a high-rise apartment building, for example. Yet no police agency is now prepared to acquire the information and the sophisticated hardware and techniques with which to make a determination on other than cursory analysis of quantitative data.

Organization of the patrol force is based upon the military model, with the hierarchy structured to identify the authority and responsibility of positions and individuals. The city is divided into geographical police areas and police districts. Each of these designates a semi-autonomous command structure to delineate the extent of command.

The police district normally retains a stable geographical boundary, with the limits based upon external considerations such as natural barriers, city limits, main urban transit routes, telephone facility limitations, etc., which would affect patrol operations and communications.

Supervision follows the military authority structure from Captain down to the rank of Sergeant. Below this rank is the police patrolman. The intent of the military structure is to allow maximum flow of information through the police organization. Essentially, a supervisor has the responsibility to act as teacher for his patrolmen. His tasks are to oversee any activity, make immediate corrections, and to ensure that any task is performed to completion efficiently and effectively.

As a practical experience, the ideal situation does not exist. Patrolmen, once they leave the roll call and the district station, operate with only minimal supervision. Supervisors, despite efforts to maximize their effectiveness, cannot exert complete control over their subordinates. The radio dispatcher assumes the role of supervisor through the communications system. The assignment of a beat vehicle, through radio communications, unavoidably usurps the command structure; however, the dispatcher also maintains a means of reinforcing his authority role through the use of sanction. A vehicle not responding to an assignment is "red-lined" by the dispatcher. In this instance, the the dispatcher reports the nonavailability of a vehicle to the District Commander. Although the dispatcher is divorced from the disciplinary system, he is instrumental in instigating such action.

The result is a negative, or at best an indefinite relationship between the street supervisor and the beat officer. Add to this situation the increasing frequency of calls for service with beat vehicles being assigned to incidents far removed from their assigned beat areas, and the experience is disconcerting. Supervisors complain that beat officers are seen once "at roll call", and beat officers complain that "patrol is non-existent" once they are on the street.

Providing the public with both protection and other service requires the police administrator to schedule his resources over time and area. In order to accomplish this task, the administrator must also determine the "balance" of factors working against the realization of department objectives. The placement of a police officer in a small geographical area is the simplest manner of deterring crime. If the area is small enough he can simply walk over to apprehend a criminal. The question is whether any city is financially able to afford such resources. The officer may be assigned a larger area. Aided by increasing his mobility (a vehicle), increasing his support facilities (radio, computerized information) and by increasing his auxiliary assistance (prisoner transportation, legal staff, sociologist, evidence experts, etc.), he may perform his task faster and remain available for calls for service. However, such specialization may "cost" a department the additional patrol force resources that would eliminate other problems. Such additional patrolmen might decrease travel time between assignments, cause some deterrence to crimes of opportunity, and reduce the amount of paper work created by individual officers.

In essence, the problems inherent in the police department require that they be studied as a totality. They have been presented singly so that each could be regarded apart from the total scope of the experiment.

It is statistically impossible to predict with any degree of accuracy the location, type or time of occurrence of any individual criminal incident. The total activity of a police department can be predicted within reasonable limits, however, in much the same fashion as private industry and commerce can predict production and sales information. The intent of these two processes are the same: To prepare the organization for a given level of activity and to control the resources expended to reach a specific goal. The difference between the operating characteristics of these organizations is that a police department's financial structure is static within a time period. A specific amount of money is committed to a police agency. The private enterprise commits a portion of incoming revenue, and this may, if necessary, be increased (or decreased) if conditions allow or demand such a change in budgeting. The peculiar aspect of police work is that, unlike most industrial and commercial enterprises, in excess of 90 percent of the police budget is for personnel salaries. Therefore there exists a longer lead time and transition time before the revision of a budget can be converted into useable resources: personnel trained, special hardware acquired. The immediate acquisition of additional resources is accomplished only through government procedural channels or at the expense of other police programs.

The lack of sophisticated data processing equipment, personnel experienced in handling such equipment and the determination of the Operations Research Task Force to operate with only practical methods limited the scope of the experiment. No additional resources were to be committed to the experiment. The design and conditions of the test would be of a practical nature.

DESIGN OF THE EXPERIMENT

The success of the St. Louis Police Department (SLPD) program with the split-force concept of patrol operations led to the basic design of the experiment. Since 1966, the SLPD has been operating a program with the patrol force divided into a "calls-for-service" force and a "preventive patrol" force. The SLPD program utilizes a computer program, designed by the Harvard Laboratory for Computer Graphics, known as SYMAP. The computer output is in the form of maps of each reporting area; these maps note the intensity of selected criminal activity. In addition, other programs compute the predicted level of calls-for-service activity for each beat. This information allows command officers to determine what number of officers and units are necessary to respond to calls for police service. The SLPD system did not take into consideration the psychological effect of beat boundary changes on the patrol officer or the preliminary planning and designation of preventive patrol force missions against criminal activity.

The present Chicago Police Department system is based upon the hand method of creating beats established in 1961; data is analyzed and beats are created by totalling calls-for-service until an arbitrarily derived "workload" is established for a beat. This method is based upon the idealistically derived criteria of "four calls-per-service per beat car." Such a call for service, workload requiring one hour for service four times per tour of duty, allows the beat officer one-half of his tour of duty for preventive patrol.

Two questions are immediately apparent in the Chicago Police Department system. What is the productivity of an individual police officer? What is an effective beat size?

The standard of one-half of a beat officer's tour of duty on preventive patrol is a measure designed to fill a void created by lack of research. In practice, the police officer spends time in relation to the characteristics of his assigned beat. Analysis of the 14th District with twenty "winter" beats revealed the presence of "magnet beats" which accounted for as much as 15 percent of the beat car assignments during a tour of duty. One beat car handled 12 calls for service on the average during an eight-hour tour of duty as compared to the district's average of five calls-for-service during an eight-hour tour of duty. In addition, these magnet beats pulled other beat cars on "assist" calls; vehicles in the 14th District had spent as much as 60 percent of this time answering calls for service and providing assist service.

One interesting aspect of the 14th District analysis was the fact that the "service time" (time to answer a call for service of any nature) was about 26 minutes. Apparently, after further analysis, the service time of a Part I incident was less than that of a miscellaneous incident. (This characteristic is noted by other research, and the same relationship is brought out by Professor Allen Bristow in his book: *Effective Police Manpower Utilization*).[1]

A beat can become so small, or so large, that distance traveled becomes a relevant factor of patrol time. One police vehicle can cover only so much geography and still be effective. The one-man versus two-man car argument now becomes an argument of safety, effectiveness and efficiency versus department policy. Other relevant and valid factors come into the beat size picture in comparing the findings of private industry with the police task. Job-related research has led to the concept of "job-expansion" as practiced by the General Electric Company. This method is employed to stimulate and motivate the employee in production. The program simply allows an employee to undertake greater dimensions in the production process, to see the results of his labor through from start to completion. Another significant point was made in the study made under the direction of Dr. Melany E. Baehr of the University of Chicago: entitled "Psychological Assessment of Patrolman Qualifications." Baehr stipulates, among other things relating to the police officer's task that "It is essential that a patrolman: . . . endure long periods of monotony in routine patrol yet react quickly (almost instantaneously) to problems. . . gain knowledge of his patrol area. . . exhibit initiative, problem-solving capacity, effective judgment, and imagination. . . . Police Officers . . . refer to it as "showing street sense."

The requirement to endure monotony is well taken when reviewing the size of some beat structures evolved from the present system in Chicago. Beats range from one mile square to two blocks square in size. The effect upon the patrolman is not considered for two reasons.

In practice, beat cars are shunted throughout the district because of calls-for-service and the assignment of the assist car. (A sample of one "fast" district indicated that a beat car answered only about 5 percent, maximum, of the calls for service on its own assigned beat.)

The beat officer is supposed to aggressively pursue criminal activity, attempt to seek and apprehend those persons who commit a crime and remove the opportunity for such an act; yet the beat officer is also supposed to remain within radio contact range for assignment to calls for service. (If so, then he is active in a sense in that he is anticipating being dispatched on a task.)

The intent of the experiment was to establish a situation in which calls for service created the size of the force necessary to respond to requests for police service and in which units conducted operations on an expanded basis. Beat cars were not to be restricted to geographic limitations. The latter stipulation was modified to conform to present department policy of placing responsibility for beat occurrences on the beat officer. As a result, the ORTE researched data from various police sources and government and commercial transportation sources. The Chicago Transit Authority bus travel schedules were adopted as the most complete data available on vehicular movement over metropolitan roadways during all time periods. The end product of the study was a beat map structure based on distance travelled within a specific time

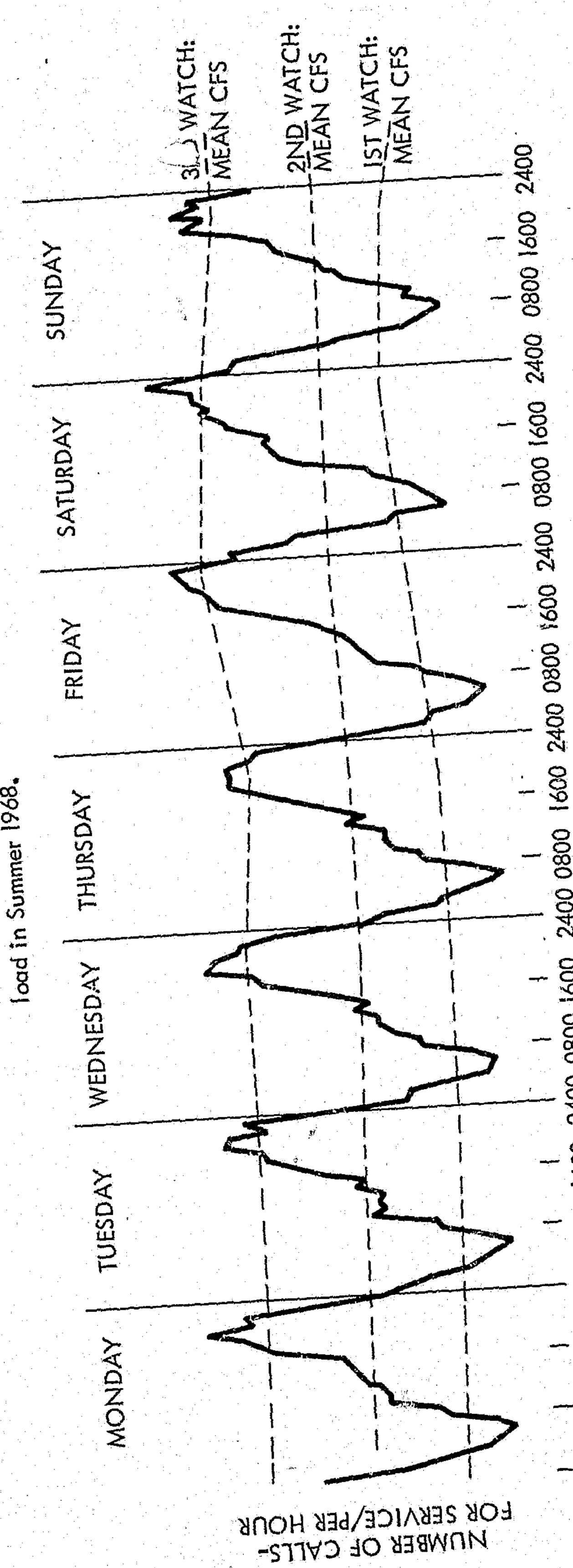


Figure 6-1: Daily stability of calls-for-service to Fourteenth District permitted forecast of the size of Response Force needed to handle load in Summer 1968.

SOURCE: CHICAGO POLICE DEPARTMENT D/S REPORT NO. CST-13

period. Each beat was constructed with the emphasis that the vehicle assigned could traverse the farthest distance of the beat within a five-minute time period. Care was taken to adapt natural and man-made barriers to cross-beat travel.

Design of the experiment as a problem was reduced by the preparation of the "five-minute-beat" map. The problem was now to simply determine the time and in what quantity police units would be assigned to the patrol structure.

In reviewing a standard department report, the "Summary of Police Activity by District by Hour," a remarkable stability was noted to exist in the percentage of calls for service by hour and by day of week. This stability was limited only to the category of the total calls for service. Tabulations of Part I and Part II crimes fluctuated erratically. "Miscellaneous-Other" calls varied less violently but still with a change of not more than 1 percent of the total number of calls. Seasonal and annual data displayed similar frequency distributions. (see Figure 6-1).

A prediction was made for the Winter Period (1968/1969) based on the historical data of the preceding season. Methodology was kept simple as all calculations were made on a standard office calculator. The total calls for service were multiplied by a predetermined factor representing the expected increase in the number of requests for police service.

Simply, it was noted that calls for service had increased or decreased at a constant rate and tended to follow historical seasonality patterns. For Summer-to-Winter, calls tend to decrease; for Winter-to-Summer, calls tend to increase. Each of these variations is subject to the annual trend toward increaseas experienced throughout law enforcement.

Examination of these trends revealed that the City of Chicago had a seasonal multiplier factor of 1.094 for the Winter Period and a 1.115 multiplier factor projection for the Summer Period. In keeping with these data, the Winter 1967/1968 statistics were multiplied by the factor 1.094; the hourly and day-of-week data were derived from the percentages indicative of the proportion of the total, and an hourly prediction by day of week was gained for the Winter 1968/1969 period. The predicted mean level of activity was *205* calls-for-service per day. Actual rate was *207* calls-for-service per day for the district.

The distributions of the calls-for-service as a total and by day-of-week were graphed for both actual and predicted data. In both cases, the only obvious discrepancy was in the range; predicted data tended to flatten (increase in range), and actual data peaked more dramatically. In both cases the data exhibited the same skewed model peaks for weekend data and the same normal peaks for weekday data. Abnormal peaks, of course, were not accounted for by this method. Although the predicted data tended to suggest a higher one-time expected peak in the number of calls for service, the actual data did not indicate any such experience.

Prior to beginning the prediction for the Summer 1969 period, an additional graph was plotted for the 1968 period. The total daily experience of calls for service in the 14th District was extracted and graphed (Figure 6-2). This chart showed no particular trends, with an exception of *one* day with an extremely abnormally high call for service. The decision to implement the experiment during the summer, as opposed to winter, came as a result of this chart. The variations in daily calls lent themselves to calculating an average in calls for service that could be handled without extra resources.

Processing the prediction for the Summer 1969 period followed the same mechanics for the previous winter prediction. The results were tabulated, charted and graphed as before. At this point, however, the other disciplines became involved in the procedures to be established for the experiment. A program was developed to compute the probability curves of service time as related to response time, versus units available for service. The program graphed a linear extension which stipulated the number of beat vehicles (response units) needed to answer a particular number of hourly incoming calls for service. For example, should calls for service (in the 14th District) be received at the rate of five per hour, and should it be decided that a vehicle should be available within six seconds to receive such call, the 14th District would have to maintain five beat vehicles in constant readiness *IF* the normal mean service time necessary to handle a call was not to exceed 35 minutes. Should any one of these variables experience deviation, the entire equation would deteriorate.

The entire experiment now depended upon the close cooperation of all concerned. A process flow chart was designed to establish the responsibilities of each of the department units that would have to participate in the experiment. A feeling for the amount of coordination required is given in the pilot program's chart of "Responsibility Areas" (Figure 6-3).

The allocation of beat vehicles to the five-minute beats was determined partially by raw figures derived from the present personnel strength of the district. However, additional resolution was gained by conferring with the district commander, the deputy chief of the Police Area involved and with the super-

Figure 6-2 : Frequency distribution of total daily calls-for-service, District Fourteen from April 25 through November 6, 1968. Used to predict workload for period of Strategic Force-Administrative test.

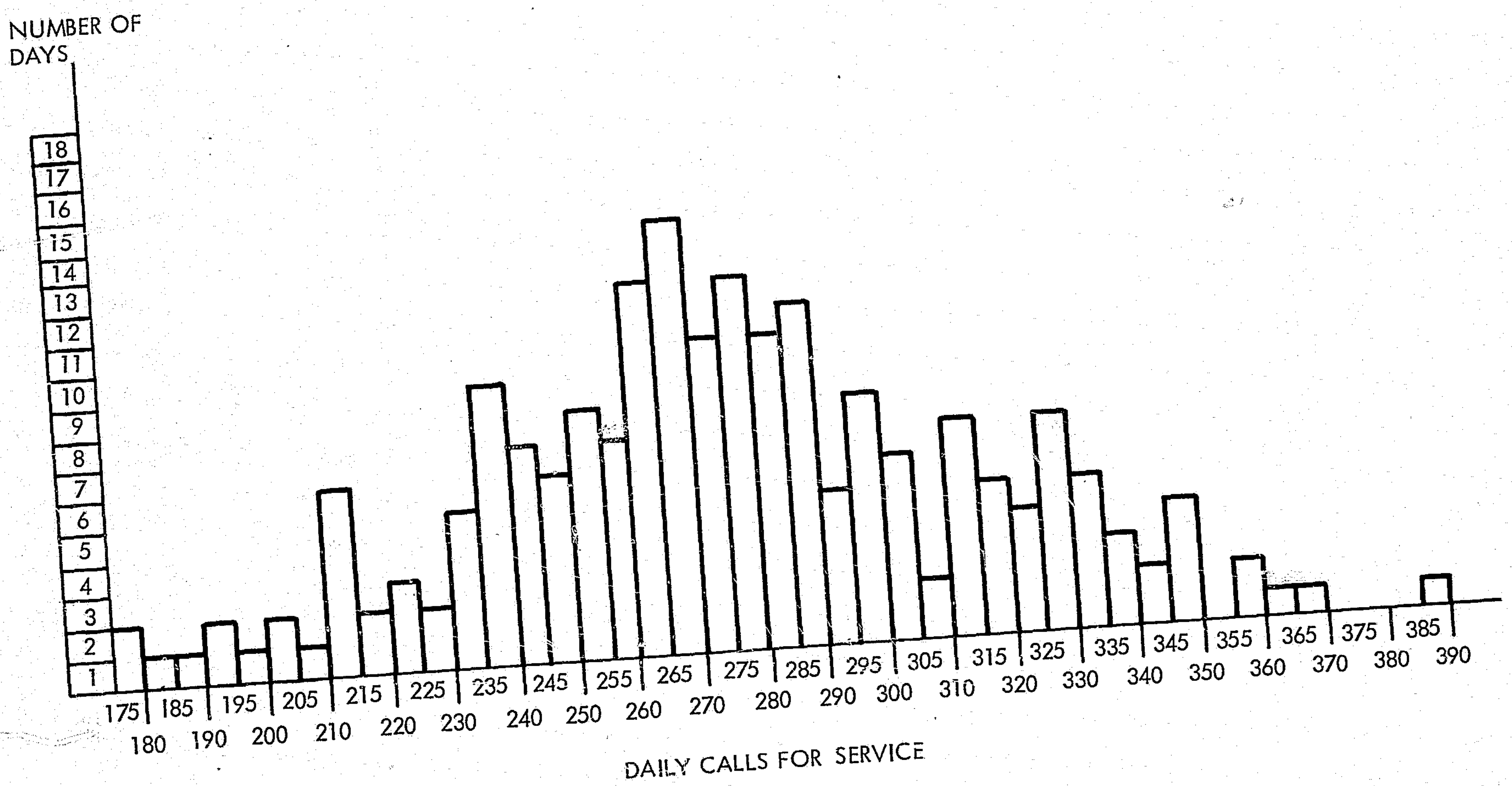
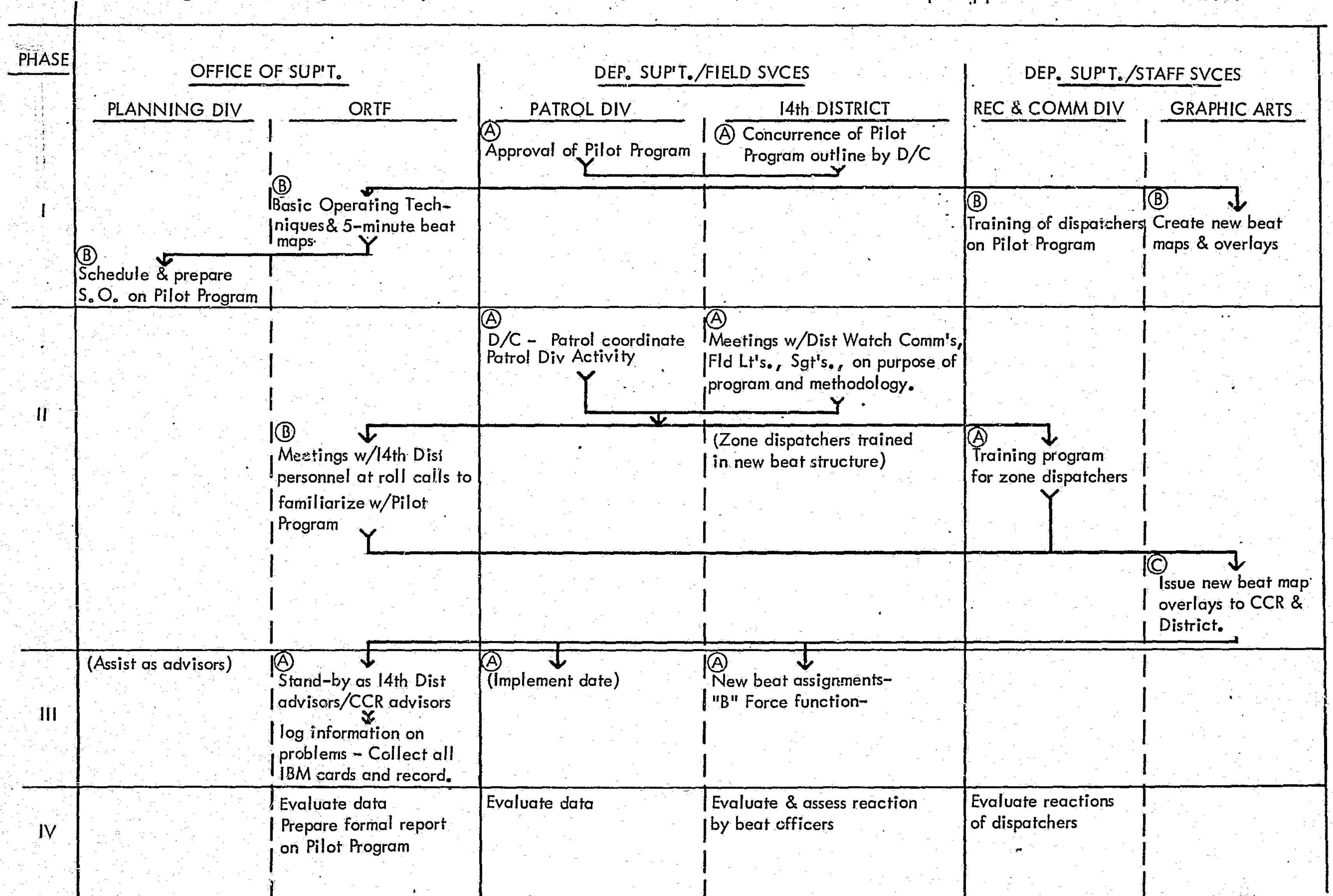


Figure 6-3: Responsibility Areas: Pilot Program - "A"/"B" Force Concept Application - 14th District



visors of the district. The 14th District in its original beat configuration consisted of 21 beats on the 3rd watch (1600 to 2400 hours); the new five-minute beat structure called for only eight "Response Force" beats.

The personnel assigned to the watch complement were to be assigned to vehicles categorized as either "Response Force" or as "Strategic Force." The new Response Force personnel had the basic responsibility to answer calls for police service as dispatched or encountered on-view. The Strategic Force personnel had a primary responsibility to complement the Response Force in answering calls for service, but would be utilized as a strategic, aggressive patrol force against specific criminal activity at particular hours of the watch. This concept demanded that the level of police activity be known for every hour of the watch and that the criminal activity most susceptible to patrol by marked police units be identified and made the subject of mission planning.

In order to motivate the district personnel, the latter objective (mission planning) was relegated to the District Tactical Unit; this organization had relevant data as to the incidence of specific crimes in the district. In effect, the new program would assist the Tactical Unit by allowing it to concentrate upon the more obvious criminal activity in strength and by still providing a patrol force capable of covering a lesser defined area without using up Tactical Unit resources.

Using the predicted calls for service data and determining the relative characteristics of each beat area (anticipated criminal activity and arrests as depicted by statistical data and as described by district personnel), vehicles were assigned to beats. An initial assignment of a Response Force vehicle was made to each of the eight beats; each beat was assigned one or two officers per car as personnel were available and historical characteristics of the beats was determined. The remaining officers were assigned to one-man vehicles, designated with a letter-suffix, to a particular beat; Beat 1403 (a two-man Response Force beat) would also have beat 1403-A (a one-man Strategic Force beat) to complement it at certain hours of the watch. At a predetermined hour of the tour of duty, the Strategic Force beat vehicles would then be withdrawn from service. These vehicles would then, under the direction of a Supervisory Sergeant, be assigned to a specific area of the district for a specific mission. The Tactical Unit of the 14th District would provide a composite outline of the major crime problems of the district for each day of the experiment.

It was recognized that the Communication Center operations would play an instrumental role in the experiment. To ease the transition from the normal operational role of the radio dispatcher to his new role in the experiment, the supervisors and dispatchers were invited to participate in preliminary discussions. The meetings resulted in a dialogue regarding the priority of assigning vehicles, and the communications personnel structured a priority schedule for assigning vehicles to various calls for service. By "stacking" such calls, depending upon the urgency for police attention, the dispatcher, in effect, applied his knowledge to a situation. The direct-talk-to-complainant concept employed in the Chicago Police radio console operation allows the dispatcher to evaluate the reported situation personally.

Data generated by field units would not change in content; however, it was also recognized that such data would take on new location and responding unit identification. The problem was resolved by making the only change necessary in the five-minute-beat map design. A new map for the 14th District was created with the assistance of department cartographers. The new map followed normal department reporting beat boundaries so that only a minor procedural change had to be made in reporting method. (See Figures 6-4 and 6-5.)

Major emphasis was placed on creating a positive attitude on the part of the beat patrolmen in the 14th District. Change of any form is resisted to some degree. The intensity of resistance is an inverse function of the amount of information regarding the proposed change. In deference to this proposition, the personnel of the 14th District was apprised of the entire experiment. Under the designation of a Pilot Program, the proposed experiment was explained in detail to all supervisory personnel in personal discussions and at meetings. The final presentation was made at a meeting of all command and supervisory officers of the district. This session covered the theory and design of the Pilot Program's conception, reasoning, and implementation.

The issuance of a department directive officially created the Pilot Program. The Department Notice outlined the duties and responsibilities of the participating units, with emphasis on minimizing formal, structured directions to police personnel. The intent of this approach was to induce a climate of freedom-of-intent of action and movement on the part of the beat officer and field supervisor. In essence, the beat officer and the Field Sergeant were to experience a police version of "job expansion." By structuring the

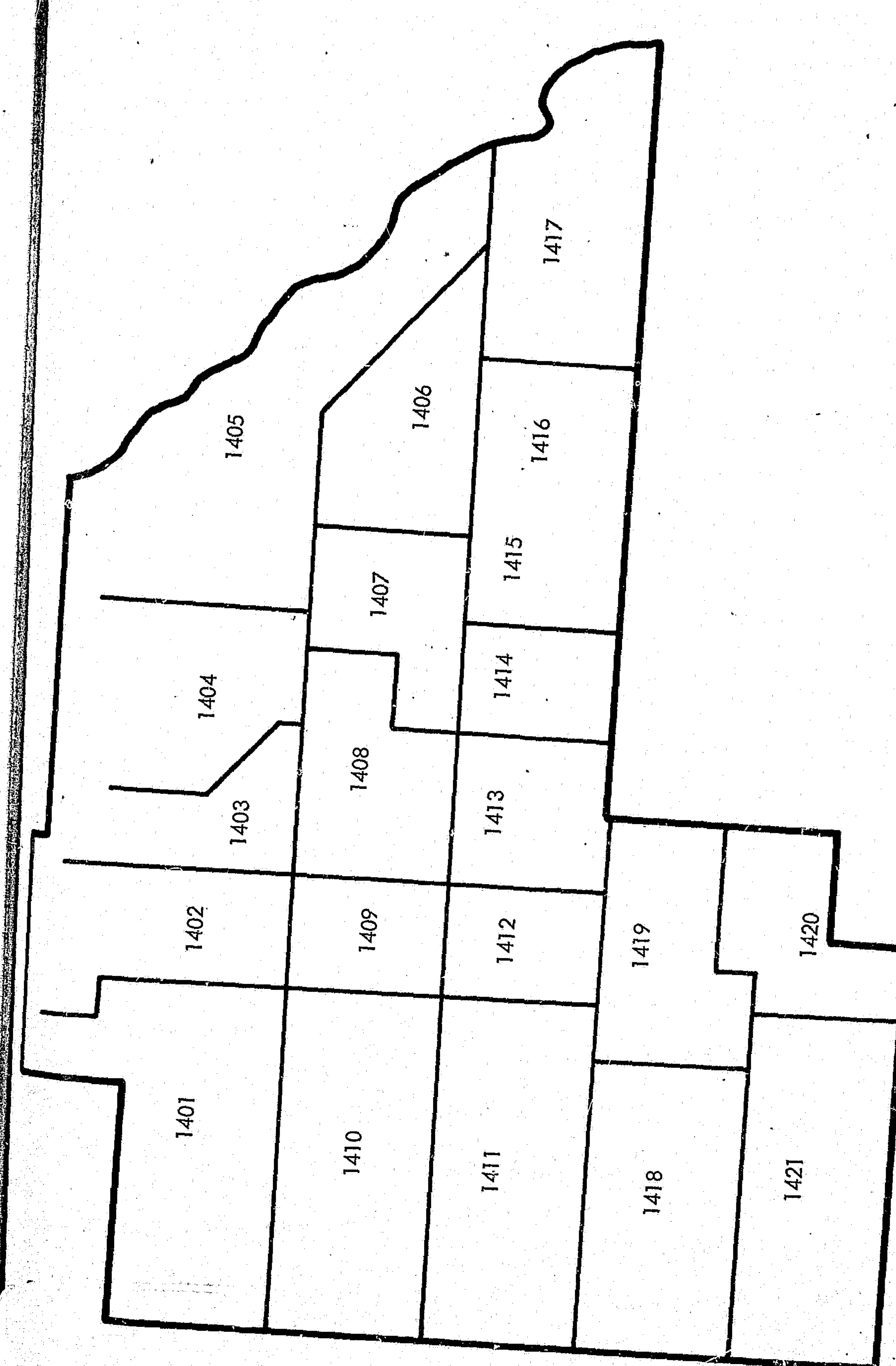


Figure 6-4: Original "five-minute-beat map" for District Fourteen (Shakespeare) patrol forecast.

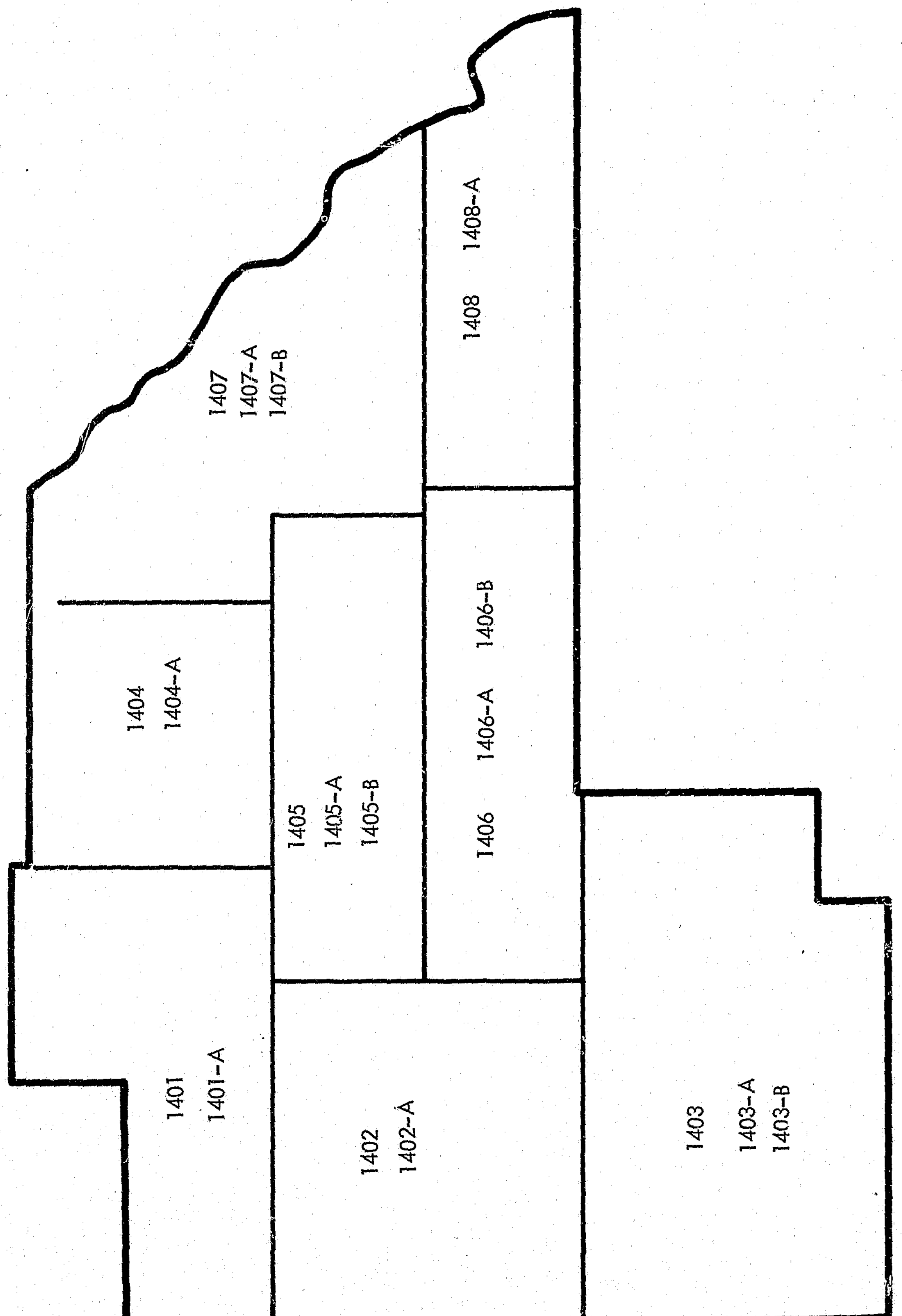


Figure 6-5: Revised beat map integrating Response Force and Strategic Force patrols under sergeants. Strategic Force units have alphabetical suffix following beat number.

Table 6-1

Supervisor's Manning Table, District 14

14TH DISTRICT/1ST WATCH

Field Lieutenant Beat 1490
Sergeant Beat 1480: Beats 1405–1406
Sergeant Beat 1481: Beats 1401–1402–1403
Sergeant Beat 1482: Beats 1404–1407–1408

AFTER STRATEGIC FORCE IN EFFECT

Field Lieutenant Beat 1490
Sergeant Beat 1480: Area East of Homan Avenue and North of North Avenue
Sergeant Beat 1481: Area West of Homan Avenue in District
Sergeant Beat 1482: Strategic Force Supervisor

2D WATCH AND 3D WATCH

Field Lieutenant Beat 1490
Sergeant Beat 1480: Beats 1405–1406
Sergeant Beat 1481: Beats 1402–1403
Sergeant Beat 1482: Beats 1401–1404
Sergeant Beat 1483: Beats 1407–1408

WHEN STRATEGIC FORCE IN EFFECT

Field Lieutenant Beat 1490
Sergeant Beat 1480: Beats 1405–1406
Sergeant Beat 1481: Beats 1401–1402–1403
Sergeant Beat 1482: Strategic Force Supervisor
Sergeant Beat 1483: Beats 1404–1407–1408

14TH DISTRICT/SQUADROL BEATS

Squadrol Beat 1470: Beats 1405–1406
Squadrol Beat 1471: Beats 1401–1402–1403
Squadrol Beat 1472: Beats 1404–1407–1408
Vice Beat 1455
All beats within Radio Zone 3

Table 6–2

First Watch Manning Table

Beat	Weekdays		Weekends		Men per car
	2330–0300/ 0030–0300	0300–0730/ 0300–0830	2330–0400/ 0030–0400	0400–0730/ 0400–0830	
1401	R	R	R	R	1
1401A	—	—	—	—	—
1402	R	R	R	R	1
1402A	—	—	—	—	—
1403	R	R	R	R	2
1403A	R	S	R	S	1
1403B	—	—	—	—	—
1404	R	R	R	R	1
1404A	—	—	—	—	—
1405	R	R	R	R	2
1405A	R	S	R	S	1
1405B	—	—	—	—	—
1406	R	R	R	R	2
1406A	R	S	R	S	1
1406B	—	—	—	—	—
1407	R	R	R	R	1
1407A	—	—	—	—	—
1407B	—	—	—	—	—
1408	R	R	R	R	1
1408A	—	—	—	—	—

R = response vehicle. S = strategic vehicle.

Table 6–3

Second Watch Manning Table

Beat	Weekdays		Weekends		Men per car
	0730–1300/ 0830–1300	1300–1530/ 1300–1630	0730–1300/ 0830–1300	1300–1530/ 1300–1630	
1401	R	R	R	R	1
1401A	S	R	S	R	1
1402	R	R	R	R	1
1402A	S	R	S	R	1
1403	R	R	R	R	2
1403A	R	R	R	R	1
1403B	—	—	—	—	—
1404	R	R	R	R	2
1404A	—	—	—	—	—
1405	R	R	R	R	2
1405A	R	R	R	R	1
1405B	S	R	S	R	1
1406	R	R	R	R	2
1406A	R	R	R	R	1
1406B	S	R	S	R	1
1407	R	R	R	R	2
1407A	S	S	S	R	1
1408	R	R	R	R	2

R = response vehicle. S = strategic vehicle.

response force size and personnel strength, the police officer could assume that the calls-for-service task would be attended to as a normal operation. In "freeing" a number of units for the strategic force, the supervisor now had to determine the most ef-

Table 6–4

Third Watch Manning Table

Beat	Weekdays		Weekends		Men per car
	1530–1900/ 1630–1900	1900–2330/ 1900–2430	1530–2000/ 1630–2000	2000–2300/ 2000–2430	
1401	R	R	R	R	2
1401A	S	R	S	R	1
1402	R	R	R	R	2
1402A	S	R	S	R	1
1403	R	R	R	R	2
1403A	R	R	R	R	1
1403B	S	R	S	R	1
1404	R	R	R	R	2
1404A	—	—	S	R	1
1405	R	R	R	R	2
1405A	R	R	R	R	1
1405B	—	—	—	—	1
1406	R	R	R	R	2
1406A	R	R	R	R	1
1406B	R	R	R	R	1
1407	R	R	R	R	2
1407A	R	R	R	R	1
1407B	S	S	S	R	1
1408	R	R	R	R	2
1408A	R	R	R	R	1

R = response vehicle. S = strategic vehicle.

fective use of these units relative to the current district situation. The situation at any point in time would not remain static since calls-for-service would fluctuate (increase or decrease) by hourly (or shorter) increments of time.

A supervisor, therefore, would have to remain cognizant of the situation in order to create a balance in his patrol force; he would be forced to a decision regarding the makup of his field units. For example, if calls-for-service increased abnormally at 0300 hours, as indicated by the number of Response Force units "down" assigned by the radio dispatcher, the supervisor must decide to release his Strategic Force units to act as backup response units or to retain the status quo for a period of time and rely on a probabilistic return-to-duty of response units. Conversely, if a calls-for-service per hour rate was low, as indicated by few radio dispatch assignments, the supervisor must decide whether to withdraw his Strategic Force units from response mode and have them begin the strategic patrol mission early in the watch or lose some effective strategic patrol opportunities.

The directive authorizing the experiment began the Pilot Program in the 14th District. It was decided to end the experiment on a specific date. The total Pilot Program would have a life of three police periods (28 days each) in which data could be generated, compiled, analyzed and evaluated by the ORTF. In addition to the directive, each supervisor received a Manning Table to guide them in preparing daily work sheets for beat personnel, a chart depicting the number of beat cars (response units) required to handle a level of radio calls of assignments, and a number of daily report forms to be issued to their Strategic Force personnel. (Tables 6–1 through 6–4.)

EVALUATION OF THE EXPERIMENT

Evaluation implies comparison, the existence of a means by which the relative effectiveness of innovation can be measured. Law enforcement lacks a single, absolute measure of effectiveness. Those quantitative statistics generated at present within the Criminal Justice System are, at best, only an indication of the magnitude of failure: The failure of the police agency to detect criminal activity prior to its commission, the failure of the judiciary and the corrections system to deter participation in criminal activity, and the failure of the citizenry to accept the obligations of responsible social association.

The oft-stated goal of the police agency is to "prevent crime." Analysis of resource expenditures, however, reveal the emphasis placed on public service. The availability of the police officer, the emphasis on the record keeping function of the police agency, serve to ensure this emphasis on public service. Relatively little time is actually spent by the individual police officer to *prevent* crime. The experiment in the 14th District was created to alleviate this situation.

The experiment stated as its objectives, to: ". . .increase the effectiveness of aggressive preventive patrol activities while providing normal police service," and ". . .provide a pilot study of an analytically-based resource allocation technique for possible city-wide application."

In addition to these stated objectives, there were sub-goals pertinent to the department's planning function:

1. Acquire expertise in the design, implementation, and evaluation of such administrative experiments.
2. Add to the knowledge of department members—information regarding police organization and operations under controlled conditions.
3. Examination and assessment of existing data and data sources in order to determine future areas of planning.
4. Assessment of the concept of predicting calls-for-service and the applicability of this methodology.
5. Assessment of the Strategic Force/Response Force concept of patrol organization and the reaction of field personnel to this form of operations.

As a practical matter, two proofs were necessary before the experiment could be considered a success: a decrease, or at best, no increase in the relative proportion of numbers of index crimes, and no deterioration in the district's level of operations.

The experiment in the 14th District can be termed successful. Analysis revealed that:

1. Calls for police service (CFS) increased as predicted. The error experienced in predicting the mean CFS per day was less than 2.0%: Predicted mean CFS = *285.6;* actual mean CFS = *288.6*; error = 1.08%.
2. No deterioration occurred in response to radio assignments. Service time per CFS increased slightly to twenty-nine minutes per call versus previous twenty-six minute factor. The "No Beat Car(s) Available" reports for the three periods indicated a loss of about 5.0 minutes per watch.

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3. Index crimes increased as expected due to the increase in the CFS. However, the recorded increase during the experiment is significantly less than expected in the categories of rape, auto theft, and theft under $50. It is suggested that these categories are subjectively more amenable to the "visibility" of the police officer deterrent. The introduction of the "Q" analysis indicates that arrests in all index crime categories increased, again adding to the deterrence effect. In line with these concept assisted by making more actual patrol time available; and that the experiment allowed the District Tactical Units to concentrate on specific crime patterns, by providing visible beat units to attack less defined areas of criminal activity.

Two results are most important. Most striking from the position of the ORTF is the stability apparent in the CFS. The accuracy of the prediction suggests that police activity is amenable to probability analysis and prediction of workloads in reporting areas to a degree greater than is now accomplished. The introduction of sophisticated equipment in order to correlate additional variables regarding an urban area may assist the police agency to develop a program to predict patrol and investigative workloads by crime category, as well as simple calls for service, as seen in Chapter 4.

Perhaps the most important qualitative results gained from the experiment is the effect of the organizational change introduced in the Strategic Force-Response Force concept of district patrol operations. To the Chicago Police Department this was a radical departure. The reports of supervisors, however, were enthusiastic regarding the change with positive comments about the elimination of the static beat structure and the introduction of "in-the-field" authority to make operational decisions concerning the deployment of patrol units. The beat officer rapidly adapted to the split-mission (response or strategic) role he was to play; the supervisors accepted the additional responsibility to preparing mission assignments and making operational decisions under stress conditions.

In retrospect, it must be stated that the ORTF erred in not providing more analytical definitions of Strategic Force mission assignments.

The error, however, is one of deliberate omission. The experiment intended that the mission assignment become the responsibility of the district supervisory personnel. Providing the data from minimal sources would only have served to detract from the experiment as a test of police capability to adapt to a changing condition. Again, it was indicative of the experimental posture of the program in the 14th District for this responsibility to be adopted by the personnel of the district and carried out.

As previously stated, the police agency lacks a single absolute measure of effectiveness with which to compare performance. By borrowing from antisubmarine warfare (ASW) techniques, the ORTF devised a partial measure, the "Q" Index, which related arrests, manpower, and criminal incidents occurring within the district. This partial measure of effectiveness presumed only to measure the change inherent in the performance of the beat officer(s), relative to the availability of patrol units. In example:

$$\text{"Q"} = \frac{\text{number of arrests}}{(\text{Hours of patrol availability})\ (\text{number of crimes})}$$

The value of "Q" in time period No. 1 would then be compared to the value of "Q" in time period No. 2. In this manner, previous time periods (prior to the experiment) could be serially compiled to provide a gross measure to be used as an Index for the experiment periods. In a like manner, pre-experiment and post-experiment data could be utilized to analyze the effectiveness of the split force organization concept of patrol unit distribution.

The computer-based analysis of the 14th District beat officers, through the "Q" measure, indicated that the beat patrolmen energetically applied their efforts towards the split force role. The ORTF expected some significant changes that might have indicated of a "Hawthorne" or "Halo" effect (perhaps an increase in so-called "efficiency" based on less desirable arrests for drunkeness, vagrancy, etc.) or other activity intended to project a better image in productivity. The results of the analysis showed no such effect. In essence, the beat officer applied himself to the implied mission of importance preventing criminal activity and taking action when opportunity presented itself. Apparently the ability to be independent of the radio was the cause of reduction in rape and auto theft; Strategic Force unit missions explicitly identified auto theft goals and, on one particular watch, the local parks and playground were established as a specific mission. (See Chapter 5 for quantitative results of "Q" comparison.)

The experiment can be termed successful in a larger sense, due to the expertise gained during the experimental program. Management now has a practical body of knowledge, normally unattainable under other circumstances, in the area of administrative experimentation.

In essence, the experiment provided the department with (1) an accurate, though not precise, method of prediction of police activity, (2) an analysis and a basis in fact as to the feasibility of the split force concept of patrol force distribution, and (3) a partial measure of effectiveness applicable to the police environment.

Evaluation (Outside View)

These comments are primarily based on a limited observation of the resource allocation experiment in the Shakespeare (14th) District of the Chicago Police Department. A more detailed supporting discussion of the theory and design of the experiment will be found in the Technical Division.

Two general observations should be made before discussing this experiment. The first has to do with administrative experimentation, that is, formal, scientifically controlled experimentation essentially under the direction of operating managers. There are two main arguments in favor of administrative experimentation.

First, the experimental method, as distinguished from study and other forms of scientific inquiry, is a very powerful method. Further, in very complex real-world situations, it is often very difficult to extract the key variables and run the experiment under laboratory conditions. The running of experiments under real conditions may be the only effective way of understanding events, and this is clearly a necessary parallel to laboratory experimentation and field study.

The second, and compelling, argument is that the manipulation of the variables in an operating organization may have unintended and unexpected consequences for other aspects of the operation. The practice of having outsiders (experimenters) select and direct these manipulations presents some difficult problems of evaluation of, and responsibility for, these consequences. In contrast, administrators of operating organizations, as they make decisions to change their operation or to improve it, are essentially carrying out experiments; and if, when they make these decisions, when they accomplish these administrative experiments, they do so with proper design, and collect the data in a planned, careful manner, the credibility of their results will be substantially improved. This will have an advantage not only in terms of the usefulness of the results to the operating organization, but also add to the general knowledge of how organizations work. In this sense, the present experiment is clearly of interest and has an importance even beyond its immediate value in terms of understanding the allocation of patrol resources and determining improved ways of using them.

The second general observation has to do with the police function itself, and on this there is an underlying agreement in the literature, not only in the theories and the reports of various experiments, but also in the reports of persons actively engaged, and experienced, in police operations. Examples include the Detroit plan to screen public service calls to cut down the work load on the beat cars and to make them more available for crime related activity and the informal comments of police officers who participated in the present experiment with the Strategic Force concept, which relieves them of activities such as turning off fire hydrants and going to a victim's home for a report of an auto-theft that happened several days before.

The common theme which emerges goes to the underlying function of the uniformed police: the "presence," the effective or available physical presence of organized society at a particular place and time, in a person who represents the physical force to carry out society's wishes in a particular situation. The crime-related activities of the police officer can be directly tied in with this concept of presence. There is, for example, the effect of the officer's presence in deterring a specific crime. The potential criminal who sees or hears a policeman anticipates that there will be direct intervention, physically forcing him to stop. This may be extended to the potential criminal's concern that the police are looking for him, or his type of act, and will try to stop him; or a concern that the victim or a witness will be aware that the police officer is available to provide a quick response, or that there will be a quick response to a call for the police because of the physical location of the police officer. In general, the protection level is high in this area because this police officer represents the potential of other police officers.

A further example is the physical presence required to apprehend and arrest the criminal. (This is usually a clear case of requiring the presence of a physical force to represent society.) The more general effects of presence include the case in which the general location of the police officer affects his availability to assist other officers, as where a number of police officers and cars are necessary to apprehend a burglar, or block off an area, or handle a major disturbance. As a general effect over time, the criminal may perceive a higher level and quality of activity; he may know that a police car on a Strategic Force patrol is not likely to be called away and know also that there is a concentration of police presence in a high-crime area.

Turning to the public service type of activity, the Detroit experience suggests that the police would identify those kinds of public service activity which are more clearly police functions as those which require an immediate physical presence from society's point of view, such as a health or safety emergency—a man drowning, or in an accident and needing first aid; or even a fire—as distinguished from guarding school crossings, the technical investigation of a crime, dusting for fingerprints or examining physical evidence of other kinds. There are probably some intermediate cases which are not peculiarly police functions.

It seems that there is this distinguishing characteristic of "presence" in somewhat the same sense that Gunnar Myrdal found in trying to develop a dimension in the *American Dilemma*. The dimension that is pervasive here is the necessity that society be represented by a physical presence, a sufficient or, if necessary, an overwhelming physical force at a particular place and a particular time.

These comments are rather closely limited to the resource allocation experiment in the 14th District which dealt with the concept of a Strategic Force in the form of a certain number of police officers and cars allocated to a patrol where they would not ordinarily be subject to a call by the Communications Center. The experiment necessarily deals with a very small part of a situation of many interrelated factors. One obvious and very important factor is the fact that the Communications Center and the Response Force are tied in to a carefully compiled set of rules and procedures and a very elaborate, thorough and complete record keeping system which allows for a considerable amount of information to be available for analysis, and which interacts with the Strategic Force and serves as a variable of interest in looking at the Strategic Force.

In the underlying theory of force-allocation, the establishment and strategy of beats, the general level of police patrol activity, training of police officers, general methods of patrol, the amounts and types of equipment, the communications system and background records on the neighborhood, there is a wide variety of factors which are not only closely related to the immediate experiment. But in some cases they represent areas of tremendous importance. These, however, are included here only when necessary to make some point with respect to the immediate experiment.

The first observation that should be made relates to the introduction of this particular administrative experiment. From a study of the records of the experiment, the paper work, the data collected and from talking with the people responsible for setting up the experiment and with some of the police officers in the 14th District who participated in the experiment, it is clear that the setting up and implementation of this particular administrative experiment were excellent. The descriptions provided elsewhere of how this was done and who did it, the steps taken and the reasons for them, will not be repeated here; the process used, the plan, and the way it was carried out, amount to an extremely effective setting up of an administrative experiment.

The data base provided in the Communications Center, the records kept by the dispatcher and the process of converting them into machine-acceptable form and the various analyses and simulation studies, have provided a base for an understanding of the patrol process and some of the key variables and, particularly, for the examination of some of the interrelationships and the testing of these interrelationships using real quantitative data. While not of direct concern in reviewing the experiment itself, these are strong supporting factors making it possible to examine some of the effects of the experiment prior to the availability of the data on the activities of the Strategic Force. While there are some limitations in the experiment which will be noted in the sections to follow, it provides encouragement to continue this type of experimentation.

Questions of the allocation of patrol time and resources, the methods of operation and geographical allocation of forms of operation and questions of whether patrols are under close control through a central dispatcher and whether they are essentially on a field patrol, are central issues. The importance of these issues requires further work, and the variables and interrelationships here are amenable to experimental research. Not only the "major" theories which appear in the journals and reports of the experiments in various police departments need to be examined in an orderly and controlled scientific fashion; there is also a need to "test" the many patrol strategies that have been worked out by the people close to the actual patrol, the supervising sergeants. They have a wealth of field knowledge and have undoubtedly experimented considerably, as in the work at Tucson, to develop more effective means of patrol. These patrol strategies need to be tested thoroughly and scientifically so that the methods which are clearly better are identified as such and so that this information is reported and made available to other police officers who may take advantage of it.

On Experiment Variables

The most evident characteristic of an experiment, as distinguished from other types of scientific research, is that some variables are manipulated, caused or expected to take on one or more values. These variables are often referred to as the independent variables. In the present experiment, the set of variables manipulated has to do with the distinction between two concepts, the Response Force and the Strategic Force. The Response Force is the beat car, assigned to a particular beat and in radio communication with the Communications Center. The Center receives calls for help and dispatches by radio the nearest or appropriate beat car, which then responds to that call. These cars normally patrol their assigned beat but are subject to redirection on a particular call at any moment. One manipulation was, for certain watches or periods of watches, to take some of these Response Force cars or beat cars and assign them as Strategic Force cars. While they are Strategic Force cars, they are assigned to patrol a particular beat area; they are on the radio for emergency calls, but they are not normally directed to respond to calls. In this form, the manipulated variables are, in terms of what one might want to measure first, the amount of time spent on "aggressive patrol" (Strategic Force vehicle or officer having more time available to spend on aggressive patrol) and the duration of uninterrupted time on patrol (the Strategic Force officer having longer periods of uninterrupted aggressive patrol). The Response Force car may be expected to patrol for shorter periods between interruptions for taking calls. So, we have here two variables which are manipulated: first, the total amount of time spent on aggressive patrol, and second, the uninterrupted time.

There are implicitly three other manipulable variables. First is the specification of patrol mission. This, initially at least, was not manipulated explicitly, the expectation being that the Strategic Force sergeant would specify the patrol mission such as looking for burglaries or for auto thefts. It was made explicit at a later point in the experiment by requesting a form from the sergeant, called "Summary of Strategic Activity", which called for him to spell out the mission descriptions. From an examination of the Strategic Force reports, it appears in a number of cases that there must have been instruction on a specific patrol mission, as where the log notes that the officer was patrolling for robbers or patrolling for auto thefts.

The second implicit manipulable variable is the geographical location of the patrol. The Strategic Force sergeant can put a number of his cars in an area where there is some reason to have a concentration, such as the expectation of a disturbance or the prevalence of a particular type of crime in the area. The third implicit manipulable variable may be a dependent variable: "morale." The morale of the Strategic Force police officer can be expected to go up considerably because he is doing more police-type activity, he has more responsibility and he has more of a work-enrichment or work-enlargement type of job. Whether morale is considered an independent or dependent variable really depends on where it is in the causal string of variables of interest. The sense of dependent variable here is a factor which is further down the causal string. In this sense, even though morale may be dependent on some other manipulations, our purposes consider it one of the manipulated variables or one or the "up-string" variables. In addition to these manipulated variables which are primarily characteristics of the Strategic Force, there is, indirectly, another variable, the availability of Response Force cars. Where some of them have been assigned to the Strategic Force, the test effectively manipulated the variable of availability of Response Force cars.

Dependent variables are those which appear down the causal string and whose measure is the outcome of our manipulations. We wish to find out how they are affected by the manipulation that we have made of the variables which are "up-string" of the dependent variables in a causal sense. There are a number of ways in the experiment to determine the dependent variables. With respect to the Strategic Force, an obvious variable is the number of arrests that the Strategic Force makes. It is not obvious, at least from the Strategic Force special study daily activity report, that there are any other dependent variables.

With respect to the Response Force, with the somewhat more detailed and complete records which are available through the Communications Center, the dependent variables include arrests, response time and the time during which no response vehicle is available. In addition, data is taken on the number of assists and whether they are voluntary or not and on the particular type of crime. There is also a relatively complete, if sometimes ambiguous, record of the time spent on each type of activity. There is also an indication of whether or not a case report was completed and there are other detailed records which provide potential information on both independent and dependent variables affecting the Response Force. In addition to these specific dependent variables for the Strategic Force and specific dependent variables related to the Response Force, there are dependent variables which cannot be segregated. These are the amount of crime reported in the district and the cost (more or less cost in terms of cars, radios, police salaries, and so on). There may on other dependent variables, but these are the ones which appear clearly.

Theory and Data

The theory behind the experiment is that aggressive patrol will result in more arrests and less reported crime, although the greater visibility of police on aggressive patrol may result in the reporting of a greater proportion of crimes committed. The results may be evaluated in terms of this theory by comparing the number of arrests per unit patrol time made by the Strategic and Response Forces, or by comparing the number of arrests and reported crime rate during the experimental period, with the figures for another period or for another district. In the first case, the definition of those activities which constitute "patrol time" is critical; multiple arrests must be distinguished from single arrests. In the second case, many factors outside the control of the experimenters may affect the results.

It is estimated that over 800 Strategic Force report forms were filled out over the period of the experiment. The information from 141 of these forms representing 15 days was put into the form of bar charts coded to show the number of hours spent on each activity by each patrol car. This is an obvious and effective presentation of the independent variables, total aggressive patrol time and uninterrupted time. Its disadvantage is the time required for preparation, in this case, the valuable time of an experienced police sergeant.

A separate analysis was made of 39 forms, representing four days, in which the data for each separate activity of each car was reduced to a single EDP card for machine analysis. EDP techniques would allow the machine generation of bar charts and the calculation of statistical analyses, including evaluation of the relationships between the variables. The disadvantage is that an algorithm is required, especially if personnel not trained to evaluate the reports are used.

In either case, the form and content of the reports required extensive interpretation and a number of problems appeared which limited the usefulness of the data, at least for the purpose of evaluating the propositions.

In the design of an administrative experiment, the theory of the expected effects should be outlined. A limited objective should be set, and manipulated variables chosen which are expected to affect advantageously some other variable and which the people concerned are willing to manipulate. The criteria for the dependent variable, independently of the manipulated variables, should be identified.

A procedure must be designed to collect data on the manipulated and dependent variables and on key parameters. The collection of unnecessary data should be avoided, test forms become too complicated, or issues of confidentiality be needlessly raised.

In this experiment, the definition of the manipulated variable patrol time depends on which activities are expected to have the deterrent effect on crime that the theory associates with aggressive patrol. There must also be a decision as to which interruptions of patrol are important for the theory and which can be disregarded in calculating uninterrupted patrol time. When patrol mission is specified, the experimenter and the patrol officers must agree on the kind of activity implied by the specification, the precision with which geographical location is to be measured must be decided, again on the basis of its importance to the theory; and morale might be measured by a questionnaire to participating officers at the end of the experimental period.

In recording the dependent variable of arrests, the crime for which the arrest was made must be specified since the theory predicts that the Strategic Force will have a deterrent effect on some crimes only. If the Response and Strategic Forces are to be compared by the number of arrests, those made as the result of a dispatch must be distinguished from "on-view" arrests. If the response time of a Strategic Force car volunteering as an assist is to be compared with that of a Response Force car, the Strategic Force officer must define response time in the same way as the Communications Center. The time during which no Response Force car is available is recorded directly by the Communications Center.

The parameters of the experiment are of three kinds. First, those which affect the accuracy of the data: methods of collecting the data; and how well the participants in the experiment understand what they should record. Second, unusual conditions at the time of the experiment whose effects exceed those of the experimental manipulations. Third, the external validity, or the extent to which variables are affected by the mere fact of the experiment taking place: in this case, the participants' knowledge that they were being studied; the persistence of a decrease in crime rate which would confound a comparison between the experimental and immediately subsequent periods; and the rise in the proportion of crime reported, which was mentioned above.

Recommendations

The allocation of patrol resources in terms of quantity, geographical distribution and patrol tactics is an area of vital importance in terms of the decisions a police administrator must make. Administrative experimentation is an important method for increasing the understanding of the effectiveness of various methods of patrol time. The present experiment clearly indicates that a data base exists upon which experiments can be built with high return for a modest cost: the potential for effective administrative experimentation, particularly the type of experiment involved here, is present. The evidence shows that implementation, the careful planning and working out of the experiment with the operational people whose cooperation is vital to its integrity, has been well done, and thus provides a basis for optimism with respect to additional experimentation. This combination of need and competence suggests the recommendation that the experiment, which is in the pilot stage, should be carried further, developed carefully, and extended to other districts; and perhaps, after a time, repeated in the same district.

The first specific recommendation is that there be a review of the various formal and informal theories of patrol effectiveness. This review might be a very modest one, listing those factors which appear in the literature, in the reflections of experienced police officers and in experiments and studies of patrol effectiveness; and all of these factors should be identified with some notion of the evidence for the relationships of one factor to another.

The second step would be to identify those variables among these factors which can be manipulated, and those dependent variables which can be measured and which bear some relationship to other dependent variables, of value to police administrators or to other people who are interested in the effectiveness and efficiency of the patrol operation.

The third step would be to take all the other factors and make a preliminary assessment of the extent to which they represent threats to the validity of an experiment examining particular relationships, according to the theory followed. Then, control them so far as possible, either by measuring them and keeping track of their values and testing to see whether they do contribute to the results seen, or by randomizing them, or by some other method.

The fourth recommendation is to consider the various data collection instruments and make sure that the data on the key variables and key parameters necessary for the actual carrying out of the experiment are obtained; and, in the process, eliminate or minimize the collection of data which either has no reasonable relationship to the theories or which can be obtained in less obtrusive or less costly fashion.

The fifth, and last recommendation is formally to set out and describe the implementation process which has been used so effectively, if in the future the implementation involves people who did not participate in the first implementation, they will have a sure guide to what worked, and, the implementation process is of value as a report on the experiment.

TECHNICAL ANALYSIS: STRATEGIC FORCE

The underlying theory for the experiment is that an aggressive patrol, especially when it is uninterrupted by potential or actual calls or directions to do something else, will have a positive effect in terms of more felony arrests. The possibility exists for a positive effect, at least over a period of time, for less crime occurring or, in a measurable sense, being reported. This last point is a difficult one because of a confounding parameter. Higher visibility of the police apparently results in a higher percentage of all the crimes that are committed being reported. So the number of crimes reported may tend to go up in response to the experimental condition. But this is a pervasive problem here and in other experiments. Given that this relatively simple statement of the supporting theory for the experiment is correct, the next step would be to evaluate the results in terms of this theory. There are two ways of evaluating this experiment. First, one could compare the "quality" of the patrol time between the strategic and Response Forces in terms of arrests. This would be a relatively simple matter of identifying the total amounts of patrol time by the Strategic Force and the Response Force, identifying the number of arrests accomplished by each and calculating which has the higher ratio.

Second, one could compare the combined activity of the Strategic and Response Forces in terms of arrests and reported crime rate, either with other periods in the same district when both the Strategic and Response Forces were operating in the Response Force Mode or with the same period in other districts. Various corrections for trends and other secular factors would be required. Both of these methods of evaluation present problems. To evaluate the Strategic against the Response Force, it is obviously very critical to identify correctly the patrol time for each and to make certain that the patrol time, especially the aggressive patrol time that theory calls for, is separated from time spent on other activities. Also, in a short experimental period, the absolute number of arrests for the Response Force and for the Strategic Force would both be very small numbers and very small changes in the definition of an arrest. For example, mixing a major felony arrest or a relevant arrest, such as an on-sight arrest for burglary, with multiple arrests, as for a street disturbance, would confound the comparison. Comparison of the Strategic and Response Force's activity with the activity of the Response Force in another period or comparison with another district raises a number of secular threats from factors which have not been controlled. These factors may offer an alternative, plausible explanation for the differences which we find in the comparison.

Data Collection

We have made a preliminary analysis of part of the Strategic Force report forms. The form is a daily activity report given each of the Strategic Force cars, and the officers in the car are called upon to keep a log in the form of separate entries for each different activity. These entires include the time at which the activity started, the time at which it concluded, the time expended, the district in which it occurred (14th District in this case), the odometer reading at the start of the activity, the location of the activity and the type of activity. After completion, this report is reviewed and approved by the supervising sergeant at the end of the shift.

The purpose of this particular preliminary analysis was to evaluate the feasibility of reducing the entire collection of perhaps 600 reports into machine-acceptable form for analysis on a computer. The second purpose was to analyze the form in order to identify

FIGURE 6–6: Guide for keypunching Strategic Patrol Data

Note: This is an algorithm for keypunching Strategic Patrol data from sheets filled out by the officer on patrol to EDP cards. If the information is not on the sheet, leave the corresponding space on the card blank. Prior to keypunching, the sheets should be arranged by date, then shift, then by ascending patrol number, and numbered in sequence, using a three-position number, i.e., 001, 002, etc.

Columns	*Instructions*
1–3	Enter the identification number (the arbitrarily assigned sequence number described above), i.e., 003
5–9	Enter the patrol number, i.e., 1403B
11–15	Enter the date with day first, then month, i.e., 11JUN
17–18	Enter the tour, i.e., 2E, using this chart:

	Early	*Late*
1st Watch	2330–0730	0030–0830
2nd Watch	0730–1530	0830–1630
3rd Watch	1530–2330	1630–0030

Using the starting time, if possible. If the times shown are ambiguous, choose any consistent code.

Columns	*Instructions*
20	Enter the number of officers in the patrol card, i.e., 2. If none were mentioned, enter 0.
21	Enter a 1 if the sergeant's signature is present; if not, enter 0.
24	Enter X if there are marks on the sheet not associated with a particular line entry and not covered above; enter Y if other problems, such as legibility or mistakes; enter Z if both occur.
30–33	Enter the start time, i.e., 0730
34–37	Enter the stop time, i.e., 0742
39–41	Enter the elapsed time in minutes, i.e., 012
43–47	Enter the mileage at start of the activity, i.e., 34222. If over 99999, ignore the first number.
49–53	Enter the location in the form of the beat number followed by a number code from 1 to 5, i.e., 14031. Use the following table:

Code	*When Used*
1	Beat number of location appears
2	Location is in the form of a street address
3	Location is in the form of a proper geographic name.
4	Location is in the form of an area from A to B
5	Location is blank, or uncertain for other reasons.

Columns	*Instructions*
57–58	If activity is identified as a "crime," use the crime code list, i.e., 60
60	Enter information on assists, using the following code:

Code	*When Used*
1	This car was assisted.
2	This car volunteered to assist another.
3	This car was assigned to assist another.
4	Not clear which.
5	Uncertain, and some basis for believing should be an assist.

Columns	*Instructions*
62	Enter number of arrests, i.e., 4. If 9 or more, enter 9.
64	Enter estimate of "confidence" in the information, using scale from 1 to 5, from most to least confident
66–78	Enter in plain text (abbreviated) description of other activity, such as administrative activity, i.e., LUNCH, PERSONAL, STRATEGIC PATROL, VEHICLE REPAIR, etc.

potential improvements in the data collection process. The analysis process used was one of studying the collection of activity reports, in the light of what was known about the purpose of the experiment, to determine what information they contained and to design an algorithm for extracting the data from the forms.

The algorithm for keypunching these data is reproduced as Figure 6-6.

The activity report reduces into two kinds of data. First there is the fixed data which is common to the report itself; then there are the individual log entries line by line, of which there would be more than one to a report. The fixed data include a number of items, and the initial step in the procedure was to go through each item and establish a preliminary evaluation of whether this information would be necessary or desirable for purposes of machine data processing. The first thing which was done was the addition of an arbitrary identification number to each form for ease in filing, referral and positive identification. This was a three-position, sequentially assigned number starting out with 001. The key identification on the forms included the following: Strategic car number, a five-position number in the form of 1403B; the date, which in this case was in five positions, with the date of the month followed by the month itself, excluding the year on the basis that there was no danger of ambiguity in that regard; and then the tour, quoted in two positions. The first position indicated first, second or third watch, the second number designated whether it was the early or late part of the watch, there being a one-hour difference between the early and late watch starting and stopping times. Generally, the names of the patrolmen and of the supervising sergeant appeared on the forms. Neither their names nor their badge numbers appeared to be information directly necessary to the machine reduction. So the coding algorithm specified that one position should be used to indicate whether there were two, one or no names of patrolmen and one position, zero or one, to indicate whether or not the sergeant signed the form. In some cases, the total mileage was given, and in some cases the starting mileage. But the distinction was not considered necessary for machine processing. Also provided was a base to indicate whether there was a question of legibility or of some mark appearing on the paper which was not accounted for. The purpose of this was to aid the analyst in selecting out those particular reports which he wanted to check to make sure that the punched card was correct. Wherever there was an ambiguity or lack of clarity or something else not accounted for, the keypunch operator was instructed to so indicate.

Turning now to the variable data on a per-line basis, part of this was relatively straightforward. Clearly the start time, finished time and elapsed time or at least the start time and finish time, should be recorded straight down the form. This procedure was similar to the Communications Center records, and this similarity would provide advantages if comparisons were desired. The appearance of the elapsed time on the form is a redundancy in the record to provide a double check on the other entries. Perhaps it also has the advantage of allowing for a quick visual inspection of the times. In any event, the decision was made to leave it in, and it is recorded in three positions in minutes. The "district of occurrence" or "dist occur" is, in all cases, 014, the 14th District.

Because the sequential number which was assigned to each form clearly will separate these forms from those for subsequent experiments in a different district, there is no purpose in including the district number. It is not immediately clear why the mileage should be included. There are several plausible reasons: It would indicate for a patrol period whether in fact the car was moving; it would give a sense of the average rate of travel for the cars on patrol; and there are some other uses. In any event, it was included. The next item was location of activity. In some cases this appeared as a beat number location. The certainty that the location information was correct on the forms varied considerably, so a confidence code was used. The pilot keypunching was done on the assumption that in every case the report was in the particular beat of the car. However, for the formal punching, a map would be used to check this. So the beat number would be included and then followed by a "one" if the beat number actually appeared on the form. A "two" would be used if the form contained a street address which had to be interpreted by going to the map. A "three' would signify a proper geographical name, such as the name of a park which had to be found on the map. Four would indicate an area, say, from point-A to point-B. Finally, if the location were blank or if there were some other uncertainty, the number "five" would be used. On the type of activity, two spaces were allocated for a crime that was reported, using the formal Chicago Police Department code for crimes, such as 00 for homicide, 10 for rape, and so on.

In some cases, the log indicated whether an assist was involved. Because, for the Response Force, the Communications Center provided information on who assisted whom and whether an assist was voluntary or not, it was decided to cover this with a single position code using the numbers 1, 2, 3, 4, 5, to indicate respectively: this car was assisted; this car voluntarily assisted; this car was assigned to assist; it is not clear whether assistance was voluntary or assigned; it is uncertain what the situation is. On arrests, a one position code was used. Zero indicated no arrest, and then 1, 2, 3, 4 and so on for numbers up to 9. Nine indicated 9 or more arrests, the rare ambiguity in the latter case requiring examination of the form. (For other activities, a two position code was initially used for things such as lunch, personal, and Strategic patrol. The purpose here was to separately identify time on patrol from time not on patrol. Eventually this was changed to provide a printout with a limited number of letters of these other activities: lunch, personal activities, Strategic patrol, vehicle repair, park check and so on.

Comments on Design

Administrative experiments are very difficult to carry out credibly, and they are always a credit to the person who tries to do them. General rules which are recommended to be followed in carrying out administrative experiments are:

Prepare for the experiment by outlining the theory or the underlying argument of what you expect to find.

Limit your objective in the experiment.

What are you going to manipulate?

What will the effect of the manipulation be on something else?

Choose a variable to manipulate such that if the experiment is a success, you or others will be willing to manipulate it in experiments for practical purposes, as distinguished from purposes of understanding some phenomenon.

It is always desirable to choose as a dependent variable some factor that you want to maximize or minimize or optimate. Or choose some variable which takes on values which are of great utility. Often this type of dependent variable is considerably separated from the independent variables on the causal string. There is not always theory to support the relationship.

Further, if there are a number of intervening steps of causality between the independent variable and the variable of interest, each of these steps provides and opportunity for some confounding variable to be introduced which will lessen the likelihood that your results will be understandable. There is an alternative, and that is to choose the dependent variable with two things in mind. One, the variable must be one that you can measure or that you can get good data on. Second, choose as the dependent variable that factor which, while not perhaps the variable you would like to measure, can at least be related to the ends that you want to achieve.

If some particular variable that you can measure is one that is believed to bear a relationship to something of value, then it is a good dependent variable. In addition, at this stage, it is desirable to identify the key parameters. These are those variables which may tend to confound your results, interact with your independent variables to cause confusion as to whether your independent variables caused the particular dependent variation which you are investigating.

After this first step of outlining the dependent and independent variables and parameters, the second stage is to design your data collection and recording process to get the data that you need to test your theory. These are data on the dependent and independent variables and on the key parameters. By inference (perhaps it can be stated explicitly), it is desirable to avoid gathering other data. The gathering of other data not only has a direct cost, but it also may degrade the data that you want in terms of raising the resistance of the sources of information, a reaction to the burden of having to fill out too long a form or too much detail or by raising issues of confidentiality. For example, if it is not important to be able to identify on the form the particular source of the information, insisting on the identity may, in some cases, affect the source's willingness to give you the information you want. The object should be to limit the data collection to the data that you perceive a need for.

Comment on Variables

Earlier, the manipulated variables were listed, and two direct variables were identified. These were the amount of time spent on aggressive patrol and the duration of uninterrupted time. Some other variables were not listed. Time on patrol is not just a question of how many minutes or how many hours were spent on patrol. Rather, in our "theory," by patrol we mean specifically of a quality or kind of activity which must be clearly separated from non-patrol activity. The first design problem is who will decide this. It could be specified to the officer, for example, so that he coded it. In the form in which it appears in the present data, we have to decide whether we include it in the algorithm for the keypunch operator or retain all the information on the form and decide later in the analysis that a particular entry will be considered patrol or not patrol.

What would be the criteria for deciding this? There are several possibilities. One is that we would distinguish between times when the car is stationary and times when it is moving. The sense of patrol is that the car and the officer move. Whether we count the time that they are standing still as patrol time is probably not an important question, but it should be decided. There may be a separate criterion as to whether the officer's time is committed or uncommitted. If his time is committed to a specific patrol responsibility, we would call that patrol. If it is a specific patrol responsibility, spending his time looking at a specific warehouse, for example, may affect some of our dependent variables with respect to that warehouse. But it might very well be inconsistent with our theory with respect to some of the other effects, such as the deterrent effect on crime of a highly visible patrol car moving around the beat area. For purposes of one dependent variable, it would clearly be patrol; for purposes of another dependent variable, it would clearly not be patrol. We are talking about two different kinds of patrol. If we go to a general patrol responsibility, such as to go throughout the district watching for auto thefts, this is relatively uncommitted patrol responsibility. This distinction might be one of our criteria. We might also think of committed vs. uncommitted time in terms of some other duty. For example, if the officer were committed to answering another call which has a priority, such as a 10-1 or a burglary-in-progress, the time that he spent in traveling to that call and his time while answering that call might not be patrol in the sense of the independent variable that we are concerned with in our theory. On the other hand, if he is answering a call which does not have an overriding priority, for example, if he is asked to pull a cat out of a tree, and if he is driving in the general patrol area, it may very well be that his activities in terms of looking out for evidence of crimes, or his visibility to others, could not be distinguished from patrol. In either case, the qualitative value of his patrol time would hardly be distinguishable from that of the Response Car. For one purpose, anyway, this is one of the distinctions which we want to draw.

Other criteria that suggest themselves are whether the officer is in or out of the car, whether his availability to answer his radio is a characteristic of his being on patrol, whether he is in a building or on the outside of buildings, and whether he is in or out of the designated patrol area. For example, when he is traveling from the station house to the patrol area, is this considered patrol time? Is his behavior any different in terms of what he does or what other people observe him doing?

In general, discussing this relatively simple variable of patrol time, we have problems of interpretation. As one extreme, an officer traveling with a specific patrol purpose in mind and appearing to others to be behaving in that fashion, is a clear case of patrol time. At the other extreme, an officer on personal business and physically out of view of others or tied up with a priority call where his attention and location are fixed, where he could not expect to be involved in preventing crime or intervening in any crime other than the one he is concerned with, or making a court appearance which might take him out of the district, is clearly not on patrol. Then we have some other activities which cannot be called patrol: lunch, dealing with a traffic violation, acting as a school crossing guard or performing crime investigation. There are cases which probably, but not certainly, come within the definition of patrol. Time spent in answering nonpriority calls, for example, or traveling to and from the patrol area, involvement in stop-and-frisks, name and premise checks, investigating an outside alarm, looking for a lost child, carrying out a specific patrol, for example, seeking commercial burglaries. This may also include patrol of a particular building or a very constrained area. These are the kinds of problems with respect to the variables which must be considered in the planning stage. All the mentioned cases refer only to one variable.

With respect to duration of uninterrupted time, if our theory says that this duration is critical because of the psychological effect upon the officer of potential interruption, then an actual interruption on his part for personal business or stop-and-frisk or lunch is not psychologically an interruption of the same kind as interruption, by the Communications Center, of patrol by a Response Force car. If our theory is concerned with patrol time itself, then any interruptions in the smooth operation of the patrol are important, and we must inquire into the fine structure of the patrol. Interruption by a traffic jam, a stoplight or any other distraction that breaks the continuity of patrol activity is open to consideration.

In terms of specifications of the patrol mission, definition of this manipulated variable in instructions

to the supervising sergeant is very different from definition by acknowledging the instructions through the log. The officer is in fact reporting patrol time when he is specifically carrying out a particular mission. Then there is the question of whether the officer understands his mission (looking for auto thefts, say) as spending his time looking for cars with keys left in them or as looking for suspicious people loitering near cars or as stopping cars with drivers who appear suspicious, and so on. Whatever the particular mission is, our theory may require that the designation of mission be followed by a type of conduct. If this is true, we should be sure that when we manipulate the variable, all the people who are supposed to be manipulated understand our intention and are manipulated in the way that we intend. Clearly this potentially involves manipulations of other variables, such as tactics in carrying out certain types of missions, and methods of police work, which are not formally and explicitly incorporated in the experiment in its present form. It is consistent with the experiment to consider this type of variable. In this form, the experiment provides a vehicle for the manipulation of a number of variables with the caution that, if too many variables are manipulated at one time, it is difficult to interpret the effects obtained.

Geographical location of the patrol is another variable. The supervising sergeant or whoever assigned the patrol distribution might send a number of Strategic Force cars into an area under saturation conditions. Obviously this variable can be manipulated in other ways. One way which requires a more sensitive type type of measurement is to record the position of the vehicle as a function of time. If there were car locators or some other type of direction finder, this would be relatively easy to instrument. In their absence, it might be possible to specify to the officer his patrol pattern, give him checkpoints and record him at the checkpoints. Also possible is manipulation in terms of very specific patrol patterns, various search strategies and even some game theory tactics using random specifications. At least the specifications given the officer should be unpredictable by an outsider as to where the police officer will be, when, and from what direction he will approach. The degree of definition necessary here as elsewhere is a function of the theory that we are trying to explore. If we have only general ideas, and we are not very sure of the relationships, then it is important that we identify our variable so that we can reconstruct the relationship with some degree of confidence.

With respect to the variable of morale, there are a number of unobtrusive measures, assuming we want to measure it. Probably a separate instrument, such as a series of informal interviews or a post-test questionnaire would be the most efficient and direct method of assessing the effect on morale of both the Strategic and the Response Force officers wrought by the experiment.

In the dependent variable of arrests, it is desirable to distinguish, as the Communications Center does and as generally appears in the data, the kind of crime: burglary, or auto theft, homicide, an indoors crime of passion, a deliberate crime committed on the street or an opportunistic crime.

The theories that the experiment is exploring distinguish those types of crime which the patrol is expected to affect, in terms of deterrence or in terms of apprehension. The problem of assaults on the street corner might be affected by an aggressive patrol, but an assault in a building bears, in theory, no relationship to the patrol. To mix these two in a single dependent variable would confound the results. If we were to compare the arrests by the Response Force with the arrests by the Strategic Force, it would be important to separate out those arrests which were the direct result of a dispatch. Otherwise it would be difficult to relate patrol time to the number of arrests. On this basis, it would be important to distinguish between "on-view" arrests and those which are the result of a dispatch.

We turn our attention to the dependent variable "response time." We have data on the response Force, and if we are comparing one Response Force car to another, the uncertainties of the data on response time may cancel out. If we were to call for a comparable time for Strategic Force cars without the data collection through the Communications Center, there would be the problem of making sure that the definition of response time by the patrolling officer was similar to the definition by the Communications Center. It might be interesting to record the response time of the Strategic Force car volunteering as an assist. This might show, for instance, if manipulation of the variable geographic location to give saturation in a high crime area resulted in a significant number of times when a Strategic Force car responded faster than an assigned car. The advantage to the Strategic Force officer of not having to communicate before committing himself, because he is not expected to stay in his area, might be a significant dependent variable.

The dependent variable of the time when no response vehicle is available will not present a problem in measurement or definition. The assumption, however, that the Communications Center will record the time when no vehicle is available in the same manner for the experimental district as for any other district may be worth checking. We might consider this time a parameter, but it is also another dependent variable, maybe an unwanted one or possibly even a wanted one. The time when no response vehicle is available may not increase when response vehicles are assigned to the Strategic Force, because of additional screening by the dispatcher. The dispatcher, having fewer beat cars available, may more quickly start the screening process to set the low-priority calls to one side if the queue of priority calls begins to get out of hand and he has already committed say, two-thirds of the cars available to him. He may at that point postpone all but priority calls to keep several cars on stand-by. If this non-linear screening is part of the dispatcher's process, then taking a set number of cars away from the Strategic Force will not necessarily be accompanied by an increase in the time when no response vehicle is available.

Knowing Parameters

Formally, the distinction between parameters and variables is that the variables are those factors which we are interested in manipulating or whose changes result from manipulation of other variables we are interested in measuring. Parameters are factors which we are not immediately or directly interested in, but they are factors we must keep track of in order to understand the relationships we are interested in. We start by identifying those parameters which are connected with the instrumentation of the experiment. This first category of parameters includes those which determine whether the data describe what in fact happened. With respect to patrol time, did the officer maintain a diary or only submit an after-the-fact summary? Should we separate out aggressive patrol time from other activities discussed in connection with patrol? There are a number of parameters which may arise out of the fact that the data are collected or interpreted by people who may not be familiar with the particular variable that we are interested in or may see the variable in a different way. If we are unaware of this, or have the awareness but lack the control over it, we have a problem.

There is a second type of instrumentation parameter related to the question of whether our experimental methods introduce conditions which may confound the experiment. There is a series of such parameters identified in the literature on experimental and quasi-experimental design. Some of these parameters are characteristic of certain types of design. Examples include unusual conditions, such as civil disorders or good weather. These may affect the crime rate during the evaluation period independently of the manipulation of patrol times or styles. Such conditions may completely dominate the dependent variables during the period of the experiment.

A third type of parameter relates to external validity. The previous examples tended to interfere with internal validity of the experiment. Internal validity is defined as the question of whether the independent variable did, in fact, cause the observed effect on the dependent variable. In contrast, the external validity is the question of generalization to other times, other environments, other places or to circumstances where there is no experiment going on. Even if, in the present case, the results of the experiment were favorable, if considerable advantage arose out of the manipulation of the independent variables, we would have to distinguish between the present case and others. Here the people participating in the experiment were well aware that they are being studied; in other circumstances, they may not be so aware.

Other factors have been reported in the literature. The "halo effect" offers an example whereby intensive patrol over a period of time tends to cause a lasting decrease in the crime rate in a particular area. If a comparison were made between the experimental period and a period of time shortly thereafter, this effect would be a confounding parameter. Another confounding parameter is the observation often made that when there is a higher visibility of the police, as through intensive patrols, the population of the district responds by increasing the number of calls for police for both public service purposes and to report more of the minor crimes than they might have reported had they felt the police were less active.

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APPENDIX A

CHICAGO POLICE DEPARTMENT ORGANIZATION*

LT. JOHN WALSH, *Chicago Police Department*

Police protection in the area that is now Chicago dates back to 1802 when an army outpost, Fort Dearborn, was established there. By 1833, Chicago was incorporated as a town with a population of 1,800. Chicago became a city on March 4, 1837; it was protected by six constables known as the City Watch. The Chicago Police Department was established in 1855. Population by that year had reached 100,000, and the city was divided into three police precincts. The first detective force was established in 1860.

The Chicago Police Department had many trying early experiences in which officers were killed or injured. In 1855 the "Beer Riots" occurred, then came the Chicago Fire in 1871, followed by the "Haymarket Riot" of 1886. The Haymarket Riot culminated in the death of seven officers from a bomb thrown over their heads. Six civilians were killed also. Sixty officers and many civilians were injured during the events leading up to the bomb-throwing and as a result of this explosion.

A mounted force was established in 1906 to meet the needs of the congested Loop area. The mounted force was composed of 40 men and horses. The force received its first three automobiles in 1908 and was completely motorized by 1915 with 50 vehicles.

The reorganization ordinance of 1913 designated that the Superintendent, Captains, Lieutenants, Sergeants and Patrolmen be called "Policemen" and that they would constitute the police force of the city. The Park Civil Service Law enacted the same year set up a separate Park District Police Department. In 1917 juvenile officers were originated, and a Crime Prevention Bureau was organized in the Chicago Police Department. A department order in 1921 changed the names of the outlying sections from precincts to district stations. At this time, departmental vehicles carried numbers on their sides and reported to their district stations every 20 minutes.

Traffic signal lights were first installed at 138 intersections in 1925. The police radio communication system was initiated in 1930. In its first year of operation there was an average of 216 calls for police service each day. This radio service was made available, also, to 13 surrounding towns. The present police Communications Center receives between 5,500 and 6,000 calls for service per day. By 1942, all district, bureau and accident prevention squads were equipped with two-way radios. The squadrol, a modern ambulance and prisoner wagon, entered the department in 1947.

The operation and administration of the department is essentially structured along functional lines. By far the most visible use of police resources lies in the Bureau of Field Services.

Naturally the level of police organization closest to Chicago residents is that of the district and the area, composed of several districts. It is within these levels that police services are delivered.

District commanders have responsibility for the patrolmen, most assigned to motorized "beats." The area of each beat is determined by the workload, and boundaries are adjusted semiannually as changes occur in the workload. Beat patrolmen respond to observed incidents of crime and to radio assignments from the Communications Center. Beat patrolmen operate in one and two-man cars, and some are assigned to specific foot routes within certain of the motorized beats or sections of the district.

District patrol is aided by small vans, known as squadrols, manned by two officers. These vehicles carry arrested persons to district stations, transport sick or injured people to hospitals and supplement the patrol cars.

The district commander has certain officers who perform specialized functions. These include plainclothes vice officers, a community-service sergeant

*Taken in part from *The Chicago Police Department Commissioner's Report, 1955* and from "A Haphazard History of the Police Department," *Chicago Police Star*, January 1966.

who is assisted by cadets, and other officers who visit elementary classrooms in the district to enlist goodwill of the youngsters.

Police areas usually contain three or four districts. Detectives, for example, are assigned in an area pattern. There are six area headquarters, and while all districts have patrolmen assigned to them, not all districts have the full range of Field Services Bureau personnel on their premises.

The Task Force, for example, is an auxiliary unit of approximately 800 members designed to be mobilized in emergencies and on other unusual occasions. The Tactical Section is decentralized to four area headquarters to provide mobile manpower where it is needed immediately. The Task Force commander reports directly to the Chief of Patrol. Included in the Task Force are a canine section, a helicopter section, and an evidence-technician crew, among others. One section, for example, provides personnel for special events such as sports, concerts, etc.

Within the Bureau of Field Services, besides the Patrol Division, lie the Youth Division, the Community Services Division, the Traffic Division and the Detective Division.

The community services division, headed by a deputy chief, initiates and coordinates programs designed to generate mutual understanding and respect between citizens and the police.

The Detective Division conducts follow-up investigations of criminal incidents, identifies and apprehends offenders, recovers property and assists in criminal investigations. It includes over 1300 members assigned to five sections: Homicide, sex and aggravated assault; robbery; burglary; auto theft, and general assignment. The first four are self-explanatory. General assignment deals with crimes such as theft, vandalism, and fraud. Each section is headed by a commander.

FIGURE A–1.

Chicago Police Manpower, by Area and District, 1968–1969

	DIVISION TOTALS BY POLICE AREA					1 May 1969	
Area	Patrol	Detective	Task force	Traffic	Youth	Area total	Percent of total
1	1,196	183	78	69	67	1,593	17.34
2	1,150	172	110	91	85	1,608	17.50
3	996	142	0	82	67	1,287	14.01
4	1,408	244	160	88	97	1,997	21.73
5	926	154	0	96	52	1,228	13.37
6	1,032	166	126	91	60	1,475	16.05
Totals	6,708	1,061	474	517	428	9,188	

Figure A-1 gives the city-wide distribution of manpower by district and area.

The Traffic Division is commanded by a Chief. It has nearly 1,000 members and is responsible for enforcement of traffic violation regulations, investigation of accidents, direction of traffic in the Loop (Chicago's central business district) and for patrol of expressways in the city.

The Youth Division has approximately 500 members. Its main responsibility is preventing or suppressing delinquent behavior by juveniles. Youth officers also investigate missing persons cases and handle adult female suspects and offenders. Policewomen are assigned to the Youth Division. Some officers of the Youth Division are assigned to certain schools within the city.

Equal in the formal organizational structure with the Bureau of Field services are the Bureau of Staff Services and the Bureau of Inspectional Services. Each is headed by a deputy superintendent, although neither commands the manpower of the Field Services head.

The Bureau of Staff Services has approximately 1,600 members, divided into eight divisions. The divisions include training, records and communications, data systems, electronics engineering, crime laboratory, central services, automotive maintenance and building maintenance. Central services provides animal care, mail delivery, equipment and supplies.

The three divisions of the Bureau of Inspectional Services contain about 500 people. Intelligence and Vice Control divisions deal with criminal activities while the Inspections division deals with conduct and performance of the Police Department's members.

Chicago has a good record of adjustment to changing conditions. Of 30 general recommendations made by the President's Commission on Law Enforcement and the Administration of Justice, the Chicago Police Department had initiated many policies and procedures that complied with these recommendations before publication of that report. More of these recommendations have been met since publication of *The Challenge of Crime in a Free Society* in 1967.

As mentioned earlier, the Chicago Police Department has established a community relations unit with staff in all district stations. It operates police-community workshops where citizens meet regularly with police officials and serve as advisors. Chicago has recruited more minority-group officers and has more nonwhite, sworn personnel than any other department in the U.S.

During training, Chicago recruits receive heavy amounts of community relations; recruits attend the academy for seven months and receive 12 hours of college credit in the social sciences through classes taught by local college faculty members. Screening of candidates for character and fitness has improved, and officers now must pass tests derived from a psychological assessment study conducted by the University of Chicago's industrial relations center. Formerly inflexible physical, age and residence requirements have been modified to admit non-residents, and the 5′8″ height requirement has been dropped to 5′7″ to accommodate many Puerto Rican aspirants.

The department has established procedures for handling citizen's grievances, and officers are now required to take periodic in-service training. Police officers have become involved in community planning efforts.

Table A–1

Chicago Police Department's Growth, 1959–68[1]

Year	Sworn	Nonsworn	Total	Ratio sworn / 1,000 population[2]
1959	10,712	458	11,170	3.02
1960	10,026	1,688	11,714	2.82
1961	10,716	1,163	11,879	3.02
1062	10,628	1,207	11,835	2.99
1963	10,314	1,388	11,702	2.91
1964	10,244	1,466	11,710	2.89
1965	10,269	1,476	11,745	2.92
1966	11,113	1,480	12,593	3.16
1967	11,428	1,428	12,915	3.25
1968	12,006	1,480	13,486	3.41

[1] Personnel strength from FBI annual *Uniform Crime Reports.*
[2] 1960 Census used as population until 1965. The 1965 population estimate from International City Managers Association, *Municipal Year Book 1968*, used from 1965 to 1968.

Table A–2

Chicago Police-Population Ratio and Standing Among 10 Most-Populous Cities in 1968

City	Population[1] (in thousands)	Sworn police[2] personnel	Ratio sworn/1,000 population
New York City	8,080	29,939	3.71
Chicago	3,520	12,006	3.41
Los Angeles	2,695	5,937	2.20
Philadelphia	2,030	7,319	3.61
Detroit	1,660	4,647	2.80
Houston	1,100	1,577	1.43
Baltimore	925	3,259	3.52
Cleveland	[3] 811	2,161	2.66
Washington, D.C.	810	3,220	3.98
Dallas	790	1,504	1.90

[1] Populations are 1965 estimates from International City Managers' Association, *Municipal Year Book*, Washington, D.C., 1968.
[2] FBI, *Uniform Crime Reports, 1968.*
[3] Cleveland—Special Census, April 1, 1965.

Salaries have increased; patrolmen earn $11,000 annually after 42 months on the job. And, in most instances, required manpower is provided as the need is assessed; the department is now increasing its strength toward the goal of 1,000 more men recommended by the International Association of Chiefs of Police.

In addition, the Chicago Police Department has supported both operations research and increased research and development of scientific and technological innovations within the department.

Table A-1 shows the effect of the increase in personnel since 1959, and Table A-2 reflects the standing of the Chicago Police Department in relation to departments in other major cities of the U.S.

APPENDIX B

APPLYING A RESOURCE ANALYSIS BUDGET*

A conventional budget lists proposed expenditures by objects of expenditures or inputs, such as salaries or office supplies. This budget is designed primarily to assure adherence to fiscal authorizations. It can be a hindrance to efficiency by making it difficult to substitute among inputs in response to changed conditions during a fiscal year.

Economy is often equated with a reduction of expenditures. However, a reduction in spending may be wasteful and inefficient, and conversely, an increase may be efficient and economical. Efficiency, in a broad sense, means simply that outputs are worth what they cost in achieving a goal at the lowest cost or getting the greatest value for any budget.

A resource analysis budget groups expenditures according to some agreed objects or programs, and it stresses estimating total financial costs to accomplish them. This structuring of a budget to Department objectives accumulates costs in more meaningful categories and affords a better assessment of proposed changes to established programs. It provides the decision-maker with a more complete view of costs and anticipated output in initiating, continuing or modifying a program.

Analyses which are a part of the resource analysis budgeting process do not make or dictate a decision and will not replace the judgment of the police administrator. They will assist him in reaching a better decision by identifying preferred courses of action.

The resource analysis budget developed by the Operations Research Task Force did not consider the "needs-first" approach to public finance which maintains that certain needs or requirements must be met, regardless of cost or without systematic consideration of other, and possibly more highly-valued, needs or requirements which may be foregone. Similarly, the "budget-first" approach under which expenditures are determined without regard to benefits (i.e. It is maintained that only a certain amount can or should be spend regardless of the value which may be associated with additional spending.) was not considered.

In general, a resource analysis budgeting system will offer the Chicago Police Department several advantages. The first one would be an improved process for decision-making. The Resource Analysis Budget affords a systematic method of exploring alternative courses of action, more efficient and less costly, for accomplishing department objectives. The budget provides a procedure for coordinating department programs toward identified common objectives. The resource analysis method of budgeting would also strengthen the initiative of the department in policy formulation.

It is assumed that the resource analysis budget system will be carried out as a separate but parallel activity while customary budget procedures are followed by the Chicago Police Department to implement program decisions.

The initial requirement upon which a resource analysis budget structure is based is identification of department objectives and, subsequently, the activities which relate to these objectives. A police department is confronted with a number of goals or objectives and a limited amount of resources with which to attain them. In building this experimental budget, the Operations Research Task Force examined the Municipal Code of Chicago, policy statements of both the Police Board and the Chicago Police Department and the department's directives. From this research, the ORTF identified these objectives:

Protection of life and property; maintenance of public peace.
Public service.
Community support.

*Principal Author: Sgt. Walter R. Gersch.

Following identification of the objectives, specified programs were structured. These programs were termed Crime Control, Quasi-Criminal Regulation, Traffic and Public Peace. These programs were further divided into subprograms of the major programs relating to the department's main objectives.

The allocation of costs to these objectives and programs was performed on both the 1968 and 1969 appropriations for the Chicago Police Department as contained in the Annual Appropriation Ordinance and in the department's budget.

The design of a budget is merely the initial, vital requirement of a resource analysis budgeting system. It is merely the framework about which the system exists.

ANTICIPATED APPLICATIONS

The crux of a system is program analysis which essentially consists of the process of determining the relevant objectives, synthesizing alternative means toward these objectives and identifying the costs and effectiveness (benefits) of each alternative. Estimation of the costs for alternatives and the estimation of how the costs are likely to vary with changes in significant program characteristics are major parts of the analysis. This cost-effectiveness analysis can be applied at three levels of choice.

First: Choice of budget-mix between broad programs, trading-off between outputs.

Second: Choosing a "mix" of subprograms and subprograms within a program (This also involves trade-offs between outputs.).

Third: Choice among different methods or a combination of inputs which may be used to attain a given objective or subprogram. (Trade-offs between outputs.) The purpose here is to determine the "least-cost" way of achieving the objective.

Analysis is most easily applied at this third level. Efficient allocation at the third level is a prerequisite to efficiency at higher levels.

An example of trade-offs between outputs could be the situation where a department faces a decision on whether to request an additional million dollars to increase its effort against organized crime or to request the funds for use in reducing robberies.

It might be possible to reveal that a given amount of money allocated to organized crime efforts will save *X*-number of people from becoming victims of organized criminal activities. These include "juice" loans, loan sharks, etc. If allocated to robbery efforts, the money might save *Y*-number of people from being seriously injured or even killed during the commission of robberies. Such a simplified analysis, alone, could not provide the decision-maker with sufficient information to make an unequivocal correct choice. But it would provide useful insight with which to improve judgmental decisions.

It may be possible to go somewhat further by restructuring the problem so that outputs of both subprograms could be expressed in the same units. We could consider victims, per se, and compare the number saved if the additional million dollars were allocated to combat organized crime or to combat robbery. Of course, if one allocation resulted in saving more victims from physical harm and the other saved victims without physical harm being a consideration, we would be able to indicate only such a trade-off.

An example of an input trade-off would assume this case. The department must respond to *X*-number of calls for service and must also investigate *Y*-number of traffic accidents. In addition, *Z*-amount of preventive patrol is desired. There are not enough trained accident investigation personnel in the traffic division to handle *Y*-number of accidents. But if sufficient untrained personnel receive training as accident investigators, going then to the traffic division, the preventive patrol efforts would be markedly reduced.

A decision is required as to whether it would be more desirable to use untrained personnel to handle traffic accidents, or whether additional personnel should receive the necessary training and reassignment to traffic the division. The effect of a reduction in preventive patrol efforts in either case must be carefully evaluated.

Cost-effectiveness analysis can be indicated by the following example. Assume a program relating to reduction of burglaries is proposed. It will cost $100,000 per year and will produce benefits which can validly be evaluated as $200,000 through reducing the amount of property taken. This program will result in a "net gain to society" of $100,000 per year. If these gains and costs were the only available information upon which to base an evaluation, it would be concluded that the program was worthwhile.

However it may be that the last $25,000 of expenditures will produce benefits worth only $10,000, consistent with the total figures presented. Clearly it would be better to spend only $75,000 and obtain benefits worth $190,000, a net gain to society of $115,000. The last $10,000 in benefits would cost more than they are worth, and the $25,000 worth of resources could be employed to better advantage elsewhere. The rule for maximizing the net gain is to equate the incremental costs and the incremental gains.

The result of the experimental manipulations of actual budgets for 1968 and 1969 into Resource Analysis Budgets is shown below. The real budget increases may be compared for the two years by this method to show the shifting allocation of resources.

Resource Allocation Budget For the Chicago Police Department
(Based on 1968 & 1969 Budgets)

SUMMARY

Program		1968 cost	1969 cost
Crime Control		$58,095,093	$69,928,966
a. Social and Economic Conditions	($912,748)		(1,052,270)
b. Value			
(1) Opportunity			
(2) Risk			
(a) Prevention	(30,271,342)		(39,915,580)
(b) Reaction	(3,037,876)		(3,599,454)
(c) Follow-Up	(23,873,127)		(25,361,662)
Quasi-Criminal		5,182,802	6,194,343
Traffic		11,220,397	13,108,235
Public Peace		7,737,896	8,824,134
Public Service		14,883,191	17,562,543
a. Emergency	(3,263,720)		(3,821,518)
b. Specialized	(8,423,900)		(9,919,179)
c. Other	(3,195,571)		(3,821,846)
Community Support		5,068,948	7,220,547
a. Community Relations	(455,425)		(727,586)
b. Human Relations	(177,944)		(191,438)
c. Public Relations	(4,435,579)		(6,301,523)
Support		27,973,365	31,329,763
Total Budget		130,161,692	154,168,531

Program: Crime Control

Subprogram: Social and Economic Conditions

Activity	1968 cost	1969 cost
Administration/Field Services	$4,618	$5,301
Administration/Crime Prevention (Supervisory and clerical)	71,177	75,978
Prevention of Crime by Juveniles		
Supervision	147,726	172,156
Other youth services	689,227	798,835
Total	912,748	1,052,270

Subprogram: Value

Sub-subprogram: Risk

Sub-subprogram: Prevention

Activity	1968 cost	1969 cost
Administration/Field Services	$69,385	$77,902
Administration/Patrol	275,439	325,969
District Law Enforcement		
Command supervision	2,750,269	3,090,483
Secretarial and clerical	819,611	989,662
Patrolling districts on foot	3,757,500	5,343,132
Providing police squad car services	10,598,669	12,848,198
Investigating vice activity	1,134,000	1,334,466
Squadrol services	3,300,000	3,877,577
Patrolling by Task Force		
Supervisory and clerical	26,969	36,831
Providing tactical patrol	3,358,536	6,541,275
Providing canine patrol	309,462	301,674
Planning	52,272	72,799
Investigating Organized Criminal Activity		
Supervisory and clerical	70,557	82,885
Analyzing licenses and vice activity	98,976	122,909
Controlling narcotic sale and use	535,128	627,404
Controlling gambling activities	371,172	433,920
Vice detection	240,665	277,892
Prostitution and obscene matter	226,836	266,106
Conducting Intelligence Surveys	1,367,766	2,217,527
Administration/Crime Prevention (Supervisory and clerical)	71,177	75,978
Prevention of Crime by Juveniles		
Supervision	147,726	172,156
Other youth services	689,227	798,835
Total	30,271,342	39,915,580

Sub-subprogram: Reaction

Activity	1968 cost	1969 cost
Administration/Field Services	$8,988	$9,587
Administration/Patrol	31,689	35,335
District Law Enforcement		
Command supervision	393,286	420,491
Secretarial and clerical	115,225	136,762
District review of cases	339,688	392,179
Providing police squad car services	2,149,000	2,605,100
Total	3,037,876	3,599,454

Sub-subprogram: Follow-Up

Activity	1968 cost	1969 cost
Administration/Field Services	$48,561	$59,458
Administration/Patrol	66,606	65,370
District Law Enforcement		
Command supervision	612,477	660,907
Secretarial and clerical	183,174	212,076
Providing police squad car services	1,042,000	1,262,978
Processing and serving warrants	693,000	815,507
Investigating vice activity	378,000	444,822
Squadrol services	670,000	789,877
Participating in trials	1,854,000	2,181,746
Patrolling by Task Force		
Supervisory and clerical	8,751	5,240
Providing canine patrol	309,463	301,674
Crime scene searches	563,274	691,004
Administration/Crime Detection		
Supervisory and clerical	310,877	317,710
Reviewing case reports	367,344	428,516
Investigating bomb & arson cases	213,010	121,768
Conducting special investigations	265,104	—
Area Crime Detection		
Secretarial and clerical	575,111	725,500
Investigating homicide, sex and aggravated assault cases	2,299,104	2,246,452
Investigating robbery cases	2,028,960	2,076,724
Investigating burglary and pawnshop cases	3,091,116	2,892,753
Investigating auto thefts	1,720,236	1,799,833
Performing general investigative assignments	2,291,220	2,298,683

Activity	1968 cost	1969 cost
Administration/Crime Prevention		
Supervisory and clerical	150,981	162,978
Agency and court liaison	102,048	118,149
Prevention of Crime by Juveniles		
Supervision	295,380	344,310
Other youth services	1,378,453	1,597,670
Conducting Traffic Investigations (Investigating hit and run cases)	358,752	418,698
Providing Department Central Services		
Supervisory and clerical	9,768	10,672
Evidence and recovered property	249,126	296,672
Central detention	613,596	712,582
Prisoner transportation	414,000	483,460
Detection of Crime by Scientific Means		
Supervisory and clerical	79,085	89,063
Performing chemical tests	63,784	93,234
Performing microscopic tool examinations	15,864	12,147
Performing firearm identifications	99,402	115,520
Performing microanalytical tests	43,294	51,304
Performing spectroscopic examinations	13,278	14,307
Performing document examinations	33,072	34,597
Performing polygraph examinations	43,877	51,556
Printing photographs	13,142	14,797
Performing scientific field assignments	288,323	327,826
Repair & maintenance of laboratory equipment	16,694	13,522
Total	23,873,127	25,361,662

Program: Quasi-Criminal

Activity	1968 cost	1969 cost
Administration/Field Services	$15,265	$16,634
Administration/Patrol	53,916	60,953
District Law Enforcement		
Command supervision	665,371	730,724
Secretarial and clerical	198,250	234,033
Providing police squad car services	4,250,000	5,151,999
Total	5,182,802	6,194,343

Program: Traffic

Activity	1968 cost	1969 cost
Administration/Field Services	$34,817	$42,221
Administration/Patrol	17,046	15,901
District Law Enforcement		
Command supervision	179,466	191,678
Secretarial and clerical	52,598	61,731
Providing police squad car services	180,000	218,162
Intersection traffic control	1,206,000	1,419,194
Administration/Traffic Direction & Safety		
Supervisory and clerical	166,927}	274,448
Traffic operations	50,304}	
Maintaining Traffic Records and Statistics		
Supervisory	30,524	33,993
Processing and maintaining traffic citations	91,027	100,173
Investigating parking meter complaints	9,427	10,258
Tracing ownership on parking violations	82,068	92,361
Performing machine processing services	292,335	320,896
Providing traffic statistics	38,298	40,939
Maintaining traffic citation files	43,077	50,121

Activity	1968 cost	1969 cost
Performing Special Traffic Services		
Supervisory and clerical	36,540	42,072
Performing courtroom assignments	316,932	423,076
Conducting Traffic Investigations		
Public passenger vehicle licenses	237,790}	318,958
Serving traffic warrants	36,000}	
Area Traffic Enforcement		
Supervisory and clerical	1,278,614	1,525,846
Investigating traffic accidents	819,000	962,689
Enforcement of motor vehicle regulations by squad car and patrolling	1,908,000	2,243,040
Enforcement of motor vehicle regulations by three wheeler motorcycle	900,000	1,065,100
Loop Intersection Control	1,946,076	2,270,424
Controlling Traffic by Radar	343,452	400,848
Maintaining Department Vehicles		
Supervisory and clerical	190,759	198,495
Repair and maintain vehicles	668,377	715,627
Repair and maintain motorcycles	55,092	57,459
Detection of Crime by Scientific Means		
Supervisory and clerical	1,090	2,660
Printing photographs	8,761	9,865
Total	11,220,397	13,108,235

Program: Public Peace

Activity	1968 cost	1969 cost
Administration/Field Services	$14,657	$15,206
Administration/Patrol	68,108	63,604
District Law Enforcement		
Command supervision	616,639	655,068
Secretarial and clerical	184,233	207,631
Providing police squad car services	834,000	1,010,896
Special details	3,807,000	4,236,400
Police service—Water Plants	125,000	117,000
Providing Special Police Services	1,207,356	1,493,504
Patrolling by Task Force		
Supervisory and clerical	6,907	5,534
Detail section	873,996	1,019,291
Total	7,737,896	8,824,134

Program: Public Service

Subprogram: Emergency

Activity	1968 cost	1969 cost
Administration/Field Services	$9,375	$9,587
Administration/Patrol	34,017	35,335
District Law Enforcement		
Command supervision	408,627	421,571
Secretarial and clerical	121,701	135,270
Providing police squad car services	1,590,000	1,927,230
Squadrol services	1,100,000	1,292,525
Total	3,263,720	3,821,518

Program: Public Service

Subprogram: Specialized

Activity	1968 cost	1969 cost
Administration/Field Services	$41,233	$47,364
Administration/Patrol	61,576	159,894
District Law Enforcement		
Command supervision	1,705,326	1,876,418
Secretarial and clerical	509,824	606,351
Providing police squad car services	57,500	69,637
Patrolling school crossings	3,422,088	3,822,448
Patrolling by Task Force		
Supervisory and clerical	1,089	1,372
Providing marine patrol	142,893	* 106,929
		166,511
Administration/Crime Prevention (Supervisory and clerical)	56,691	64,562
Prevention of Crimes by Juveniles		
Supervision	117,684	147,085
Providing school patrol	549,000	678,699
Administration/Traffic Direction & Safety (Safety education training)	163,824	170,026
Investigating Organized Criminal Activity	20,215	22,299
License investigations	438,672	505,848
Providing Department Central Services		
Supervision and clerical	9,820	11,538
Auto pounds	898,236	1,202,484
Animal care	228,224	259,714
Total	8,423,900	9,919,179

* New helicopter patrol cost.

Subprogram: Other

Activity	1968 cost	1969 cost
Administration/Field Services	$7,273	$7,524
Administration/Patrol	28,085	26,501
District Law Enforcement		
Command supervision	305,458	316,263
Secretarial and clerical	92,047	102,981
Providing police squad car services	496,168	602,195
Squadrol services	1,032,000	1,220,719
Police service—O'Hare Field	737,524	969,737
Administration/Crime Prevention (Supervisory and clerical)	9,454	14,172
Inspection of Entertainment Exhibitions	111,536	122,983
Maintaining Police Records and Communications		
Supervisory and clerical	22,353	25,105
Processing police inquiries and records	353,673	413,666
Total	3,195,571	3,821,846

Program: Support

Activity	1968 cost	1969 cost
Administration/Departmental	$263,972	$283,402
Finance Services	166,020	224,997
Personnel Services	1,127,798	1,086,551
Police Planning Services	367,467	432,044
Public Information Services	252,655	244,938
Administration/Staff Services	61,468	65,312

Activity	1968 cost	1969 cost
Maintaining Police Records and Communications		
Supervisory and clerical	52,157	58,580
Processing police inquiries and records	915,431	1,087,152
Maintaining Police Communications		
Supervisory and clerical	317,059	696,036
Receiving and dispatching complaint calls	2,075,554	2,424,398
Operating police administrative switchboard	156,555	173,911
Operating teletype equipment	101,082	198,211
Providing records control numbers	108,000	126,300
Coordinating telephone installation & repair	382,336	
Performing Police Identifications		
Supervisory and clerical	91,116	102,363
Processing photos	6,636	7,669
Processing fingerprints	421,909	480,277
Identifying latent prints	144,720	226,425
Maintaining arrest records	132,352	166,572
Processing field inquiries	613,624	704,018
Providing Department Central Services		
Supervisory and clerical	6,812	6,634
Providing equipment and supplies	1,343,821	1,586,071
Providing graphic art service	303,684	330,634
Department mail service	381,759	431,483
Maintaining Department Vehicles	4,014,221	4,251,972
Maintaining Departmental Buildings	1,614,937	1,706,658
Maintaining Departmental Radios		
Supervisory and clerical	240,562	250,770
Mobile radio field service	269,568	349,416
Shop service—electrical	285,311	363,975
Shop service—radio	938,624	858,913
Maintain transmitters	169,326	210,050
Training Police Personnel		
Basic programs	493,862	
Special programs	247,994	
Special skills	223,693	1,215,128
Data Systems Division	1,902,783	1,951,806
Administration/Inspectional Services	75,944	84,031
Conducting Internal Investigations	891,676	1,401,705
Conducting Department Inspections	259,591	10,539
Administration/Field Services	10,481	38,869
Administration/Patrol	68,259	
District Law Enforcement		
Command supervision	423,950	462,589
Secretarial and clerical	126,243	146,287
Care and custody of prisoners	1,440,000	1,694,560
In-service training	2,085,037	2,426,917
Uniform allowance	2,397,425	2,761,600
Total	27,973,365	31,329,763

Program: Community Support

Subprogram: Community Relations

Activity	1968 cost	1969 cost
Administration/Field Services	$467	$698
Community Services Division		
Supervision and clerical	25,304	31,532
Community Relations Section	429,654	695,356
Total	455,425	727,586

Subprogram: Human Relations

Activity	1968 cost	1969 cost
Administration/Field Services	$221	$127
Community Services Division		
Supervision and clerical	10,335	8,509
Human Relations Section	167,388	182,802
Total	177,944	191,438

Subprogram: Public Relations

Activity	1968 cost	1969 cost
Administration/Field Services	$11,203	$15,301
Administration/Patrol	46,182	55,653
District Law Enforcement		
Command supervision	477,897	672,579
Secretarial and clerical	142,797	214,859
Patrolling districts on foot	3,757,500	5,343,131
Total	4,435,579	6,301,523

Method of Allocating Costs

The Annual Appropriation Ordinance for the City of Chicago in 1968 allowed the Police Department a budget of $130,161,692. Of this amount, 93 percent or $121,167,145, was for personal services, salaries. The departmental budget yielded a distribution of these appropriations by organizational activity, of which there were 37. In preparing a Police resources analysis budget, the total costs of 23 organizational activities were allocated to programs or subprograms on the basis of the nature of the organizational activity. Similar distributions were made to produce a resource analysis budget for 1969.

The remaining 14 organizational activities contributed to more than one program. This required a breakdown of the costs into sub-activities. The cost of these sub-activities was then assigned to subprograms of the resource analysis budget. How these distributions were handled is apparent from the line-by-line budget item conversions which follow.

The Records and Communications Division reported that 60 percent of the activities of the Records Unit, Records Inquiry Section, were expended in non-police services. The cost of this portion of the sub-activity, "Processing police inquiries and records," were allocated to the sub-program "Public Service-other." The amount: $353,673.

Based on estimates of the division, 30 percent of the cost of the sub-activity, "Maintaining police records and communications—supervisory and clerical," was allocated also to the subprogram "Public Service—other."

Organizational activity	Program/ subprogram
Administration/Departmental ($263,972)	Support
Finance Services ($166,020)	Support
Personnel Services ($1,127,798)	Support
Police Planning Services ($367,467)	Support
Public Information Services ($252,655)	Support
Administration/Staff Services ($61,468)	Support
Maintaining Departmental Buildings ($1,614,937)	Support
Maintaining Departmental Radios ($1,903,391)	Support
Training Police Personnel ($965,549)	Support
Data Systems Division ($1,902,783)	Support
Administration/Inspectional Services ($75,944)	Support
Conducting Internal Investigations ($891,676)	Support
Conducting Department Inspections ($259,591)	Support
Conducting Intelligence Surveys ($1,367,766)	Prevention
Providing Special Police Services ($1,207,356)	Public Peace
Administration/Crime Detection ($1,156,335)	Follow-up
Area Crime Detection ($12,005,747)	Follow-up
Inspection Entertainment Exhibitions ($111,536)	Public Service—Other
Traffic Records and Statistics ($586,756)	Traffic
Providing Special Traffic Services ($353,472)	Traffic
Area Traffic Enforcement ($4,905,614)	Traffic
Loop Intersection Control ($1,946,076)	Traffic
Traffic Control by Radar ($343,452)	Traffic

The balance of the cost of maintaining police records and communications ($5,518,531) was allocated to the program "Support."

Costs of the activity "Providing Department Central Services" required an extensive breakout. After sub-activities were determined, their costs were allocated to the Resource budget as follows:

Central Services

Subactivity	Program/ subprogram
Evidence and Recovered Property Section ($249,126)	Follow-up
Equipment and Supplies Section ($1,343,821)	Support
Graphic Arts Section ($303,684)	Support
Auto Pounds Section ($898,236)	Public Service—Specialized
Mail Delivery Section ($391,759)	Support
Animal Care Section ($228,224)	Public Service—Specialized
Central Detention Section ($613,596)	Follow-up
Prisoner Transportation ($414,000)	Follow-Up

Based upon the number of personnel assigned and the program or subprogram to which each of the above functions were charged, portions of the cost of the supporting sub-activity, "Supervisory and clerical," $26,400, were allocated to programs and subprograms as follows:

Program/subprogram	Amount
Follow-Up	$9,768
Public Service-Specialized	9,820
Support	6,812

Crime Laboratory records indicated a similar divergence for funds in the area of "Detection of Crime by Scientific Means." Forty percent of the total effort of the sub-activity of the laboratory called "printing photographs" was devoted to providing traffic accident photographs. Thus 40 percent of the cost ($8,761) was charged to "Traffic." A proportionate share of the cost of the supporting sub-activity "supervision and clerical" ($1,090) was also charged to Traffic. All other costs of the laboratory activity, "Detection of Crime by Scientific Means," ($709,635) were allocated by sub-activity to the program "Follow-Up."

Allocation of costs for the organizational activity "Maintaining Departmental Vehicles" was initiated by first determining the portion of department vehicles assigned to the Traffic Division. Based on this, 20 percent of the cost of the sub-activity "Repair and maintain vehicles" ($668,377), including cost of new vehicles, was charged to the program Traffic. The same program also received a proportionate share of the cost of the supporting sub-activity "Supervision and clerical" ($190,759).

All other costs ($4,014,221) were allocated by sub-activity to the program "Support."

"Investigating Organized Criminal Activity" also divided into several programs. A proportionate share of the supporting sub-activity, "Supervision and clerical" ($20,215) was charged to the program "Public Service—Specialized." The balance ($70,557) was allocated to the program "Prevention." The remainder of the $2,002,221 activity was allocated as shown:

Subactivity	Cost	Program
Analyzing licenses and vice activity	$98,976	Prevention.
Controlling narcotic sale and use	535,128	Prevention.
Controlling gambling activities	371,172	Prevention.
License investigation	438,672	Public Service—Specialized.
Vice detection	240,665	Prevention.
Prostitution and obscene matter	226,836	Prevention.

The Community Services Division received, in the allocation, its own appropriation ($233,201) and the money alloted to a sub-activity of the Patrol Division, the salaries ($399,480) for the "community relations section." Since all funds were appropriated for personal services, the division of costs was based upon personnel assignments. The sub-program Community Relations received $429,654, and the sub-program Human Relations received $167,388. Proportionate shares of the supporting sub-activity "supervision and clerical" were then allotted to Community Relations ($25,304) and Human Relations ($10,335).

Patrolling by Task Force

Costs of the organizational activity, "Patrolling by Task Force" ($5,653,617) were divided into sub-activity costs and allocated to programs as follows:

Subactivity	*Program/subprogram*
Providing tactical patrol ($3,358,536)	Prevention.
Providing marine partol ($142,898)	Public service—specialized.
Providing canine patrol ($618,925)	Prevention ($309,462); Followup ($309,463).
Detail section ($873,996)	Public Peace.
Planning ($52,272)	Prevention.
Crime scene searches ($563,274)	Followup.

Costs of the supporting sub-activity, "Supervision and clerical," $43,716, were divided based upon personnel strength assignments, and were allocated to programs and subprograms as follows:

Program/subprogram	*Amount*
Prevention	$26,969
Followup	8,751
Public peace	6,907
Public service—specialized	1,089

DISTRICT LAW ENFORCEMENT

For the police official and the student of resource budgeting, the organizational activity "District Law Enforcement" offers one of the more challenging problems as well as interesting insights into police operations. The activity, in 1968, received $65,517,459 or half of the total police budget. This figure does not include $399,480 previously transferred to the Community Services division. The district activity includes four sub-activities which contributed to multiple programs; each required extensive computation to arrive at an allocation. The costs of 13 other sub-activities were charged directly to programs or subprograms as follows:

Subactivity	*Program/subprogram*
District review of cases ($339,688)	Reaction.
Patrolling districts on foot ($7,515,000)	Prevention ($3,757,500); public relations ($3,757,500).
Intersection traffic control ($1,206,000)	Traffic.
Processing and serving warrants ($693,000)	Followup.
Investigating vice activity ($1,512,000)	Prevention ($1,134,000); Followup ($378,000).
Care and custody of prisoners ($1,440,000)	Support.
Participating in trials ($1,854,000)	Followup.
Patrolling school crossings ($3,422,088)	Public service—specialized.
Special details ($3,807,000)	Public peace.
In-service training ($2,085,037)	Support.
Police service—O'Hare Field ($737,524)	Public service—other.
Police service—water plants ($125,000)	Public peace.
Uniform allowance ($2,397,425)	Support.

The first sub-activity of "District Law Enforcement" that required further computation was "Providing squadrol police services." Previous study by the department (Planning Division Project 63-104-1: *Squadrol Use and Design*) showed that squadrol personnel devoted the following percentages of total time available to performing the services shown:

Service	*Percent of total time*
Transportation of prisoners	11
Transportation of sick and injured	18
Preventive patrol	54
Miscellaneous activity	17

The application of these percentages into the total cost for the sub-activity, "Providing squadrol police services," $6,102,000, resulted in the following cost allocations to programs and subprograms:

Program/subprogram	*Amount*
Prevention	$3,300,000
Followup	670,000
Public service—emergency	1,100,000
Public service—other	1,032,000

Squad Car Allocation

Considering the intricate nature of police patrol, program allocation of the sub-activity "Providing police squad car services" offered one of the projects major challenges. These services cost $21,197,337, and allocation to programs and sub-programs followed department policy and a study of calls for police service. Department policy states that manpower resources are allocated to the Patrol Division in sufficient number to provide approximately four hours for preventive patrol to each unit on each tour of duty. Thus 50 percent of the total cost ($10,598,669) was allocated to the sub-program Prevention.

A study and grouping of 47,102 calls for police service provided a logical basis for apportioning the balance of costs of this sub-activity ($10,598,668) to programs and subprograms. Calls were grouped into eight categories, and the percentage of the total number of calls represented by each category were determined. These percentages were then applied to $10,598,668 and the resultant costs allocated to programs or sub-programs as shown below:

Calls	Category of call	Percent of total	Cost	Program/subprogram
9,550	Offense complaint	20.276	$2,149,000	Reaction.
4,630	Followup nature	9.830	1,042,000	Followup.
3,706	Disturbance	7.868	834,000	Public peace.
18,887	City ordinance	40.099	4,250,000	Quasi-criminal.
800	Traffic	1.698	180,000	Traffic.
7,065	Emergency	15.000	1,590,000	Public service—emergency.
254	Special	.542	57,500	Public service—specialized.
2,210	Miscellaneous	4.687	496,168	Public service—other.

Command Supervision

As might be expected, unraveling the intricate relationship of command supervision to programs in the Resource Analysis Budget becomes quite complicated for the systems researcher. Authorized strength ceilings for each sub-activity of the Patrol Division were drawn from the Annual Appropriations Ordinance for the Year 1968 (p. 208). Total strength of the division, less 41 personnel transferred to the Community Services Division, was divided into authorized strengths for each sub-activity to determine a percentage of the total represented in each sub-activity. These percentages were applied into the total appropriation for "District Law Enforcement—Command Supervision" ($8,538,766) to develop costs of command supervision for each sub-activity. This follows:

Subactivity	Strength	Percent of total	Cost
Secretarial and clerical	428	5.3	$452,555
District review of cases	45	.6	51,233
Patrolling districts on foot	860	10.6	905,109
Police squad car services	2,992	36.9	3,150,804
Intersection traffic control	134	1.7	145,159
Processing and serving warrants	77	.9	76,848
Investigating vice activity	168	2.1	179,314
Care and custody of prisoners	160	2.0	170,775
Participating in trials	206	2.5	213,469
Patrolling school crossings	1,529	18.8	1,605,288
Squadrol services	778	9.6	819,722
Special details	423	5.2	444,016
In-service training	223	2.7	230,547
Police service—O'Hare Field	78	.9	76,849
Police service—water plants	13	.2	17,078
Total	8,114		8,538,766

Strength totals shown in each breakdown of costs of specific sub-activities indicate *supported strength* rather than Patrol Division total strength. For example, the total strength shown above is 8,114 since it does not include 770 command personnel who provide the services of the sub-activity to the Patrol Division.

The costs of command supervision of 12 of the sub-activities were assigned to programs and subprograms as follows:

Subactivity	Costs	Program/subprogram
District review of cases	$51,233	Reaction.
Patrolling districts on foot	905,109	Prevention ($452,555); public relations ($452,554).
Intersection traffic control	145,159	Traffic.
Processing and serving warrants	76,848	Followup.
Investigating vice activity	179,314	Prevention ($134,486); followup ($44,828).
Care and custody of prisoners	170,775	Support.
Participating in trials	213,469	Followup.
Patrolling school crossings	1,605,288	Public service—specialized.
Special details	444,016	Public peace.
In-service training	230,547	Support.
Police service—O'Hare Field	76,849	Public service—other.
Police service—water plants	17,078	Public peace.

The following breakdown of the costs of command supervision for the sub-activity, "Providing police squad car services" ($3,150,804), was determined utilizing the percentages of total calls for service developed to allocate costs of that sub-activity, discussed earlier.

Program/subprogram	*Amount*
Prevention	$1,575,402
Reaction	321,382
Followup	154,389
Public peace	122,882
Quasi-criminal	630,162
Traffic	25,206
Public service—emergency	239,461
Public service—specialized	9,452
Public service—other	72,468

Portions of the cost for command supervision of the sub-activity, "Squadrol services" ($819,722), were determined based upon percentages of total time spent on specific assignments. Using these percentages, the following costs were assigned to programs or subprograms shown:

Program/subprogram	*Amount*
Followup (11%)	$90,169
Public service—emergency (18%)	147,550
Prevention (54%)	442,650
Public service—other (17%)	139,353

The cost of command supervision of the sub-activity, "Secretarial and clerical" ($452,555), was allocated to programs or subprograms after first determining the percentage of total supported strength represented by each of the other 14 sub-activities of the Patrol Division.

These percentages were then applied into the total cost and amounts were charged to sub-activities as follows:

Subactivity	Strength	Percent of total	Amount
District review of cases	45	0.6	$2,715
Patrolling districts on foot	860	11.2	50,686
Police squad car services	2,992	38.9	176,044
Intersection traffic control	134	1.7	7,693
Processing and serving warrants	77	1.1	4,978
Investigating vice activity	168	2.1	9,504
Care and custody of prisoners	160	2.1	9,504
Participating in trials	206	2.6	11,766
Patrolling school crossings	1,529	19.9	90,058
Squadrol services	778	10.1	45,708
Special details	423	5.5	24,892
In-service training	223	2.9	13,124
Police service—O'Hare Field	78	1.1	4,978
Police service—water plants	13	.2	905
Total	7,686		452,555

These costs were then charged to programs or subprograms in accordance with percentages of total efforts developed for each sub-activity as previously discussed:

Subactivity	Cost	Program/subprogram
District review of cases	$2,715	Reaction.
Patrolling districts on foot	50,686	Prevention ($25,343); public relations ($25,343).
Police squad-car services	176,044	Prevention ($88,022); followup ($8,626); quasi-criminal ($35,209); public service—emergency ($13,389); reaction ($17,956); public peace ($6,866); traffic ($1,408); public service—specialized ($528); public service—other ($4,040).
Intersection traffic control	7,693	Traffic.
Processing and serving warrants	4,978	Followup.
Investigating vice activity	9,504	Prevention ($7,123); followup ($2,376).
Care and study of prisoners	9,504	Support.
Participating in trials	11,766	Followup.
Patrolling school crossings	90,058	Public service—specialized.
Squadrol services	45,708	Prevention ($24,683); followup ($5,028); public service—emergency ($8,227); public service—other ($7,770).
Special details	24,892	Public peace.
In-service training	13,124	Support.
Police service—O'Hare Field	4,978	Public service—other.
Police service—water plants	905	Public peace.

The total allocations of costs of command supervision are as follows:

Program/subprogram	*Amount*
Prevention	$2,750,269
Reaction	393,286
Followup	612,477
Public peace	616,639
Quasi-criminal	179,466
Public service—emergency	408,627
Public service—specialized	1,705,326
Public service—other	305,458
Public relations	477,897
Support	423,950
Total	8,538,766

Table B-1

Allocation of Costs of District Law Enforcement—Command Supervision, 1968

Subactivity	Prevention	Reaction	Followup	Public peace	Quasi-criminal	Traffic
Secretarial and clerical	$145,176	$20,671	$32,774	$32,663	$35,209	$9,101
	(25,343)	(2,715)	(8,626)	(6,866)	....	(1,408)
	(88,022)	(17,956)	(4,978)	(24,892)	....	(7,693)
	(7,128)	....	(2,376)	(905)	....	....
	(24,683)	....	(11,766)	....	....	....
	....	....	(5,028)	....	....	....
District review of cases	....	51,233	....	....	....	....
Partolling districts on foot	452,555	....	....	....	....	....
Police squad car services	1,575,402	321,382	154,389	122,882	630,162	25,206
Intersection traffic control	....	....	....	....	....	145,159
Processing and serving warrants	....	....	76,848	....	....	....
Investigating vice activity	134,486	....	44,828	....	....	....
Care and custody of prisoners	....	....	....	....	....	....
Participating in trials	....	....	213,469	....	....	....
Patrolling school crossings	....	....	....	....	....	....
Squadrol services	442,650	....	90,169	....	....	....
Special details	....	....	....	444,016	....	....
In-service training	....	....	....	....	....	....
Police service—O'Hare Field	....	....	....	....	....	....
Police service—water plants	....	....	....	17,278	....	....
Cost by program	2,750,269	393,286	612,477	616,639	665,371	179,466

Table B-1

Allocation of Costs of District Law Enforcement—Command Supervision, 1968. (Continued)

Subactivity	Public service—emergency	Public service—specialized	Public service—other	Public relations	Support	Total cost for sub-activity
Secretarial and clerical	$21,616	$90,586	$16,788	$25,343	$22,628	$452,555
	(13,389)	(528)	(4,040)	....	(9,504)	....
	(8,227)	(90,058)	(7,770)	....	(13,124)	....
	....	....	(4,978)	....	....	....
District review of cases	....	....	....	....	....	51,233
Patrolling districts on foot	....	....	....	452,554	....	905,109
Police squad car services	239,461	9,452	72,468	....	....	3,150,804
Intersection traffic control	....	....	....	....	....	145,159
Processing and serving warrants	....	....	....	....	....	76,848
Investigating vice activity	....	....	....	....	....	179,314
Care and custody of prisoners	....	....	....	....	170,775	170,775
Participating in trials	....	....	....	....	....	213,469
Patrolling school crossings	....	1,605,288	....	....	....	1,605,288
Squadrol services	147,550	....	139,353	....	....	819,722
Special details	....	....	....	....	....	444,016
In-service training	....	....	....	....	230,547	230,547
Police service—O'Hare Field	....	....	76,849	....	....	76,849
Police service—water plants	....	....	....	....	....	17,078
Cost by program	408,627	1,705,326	305,458	477,897	423,950	8,538,766

Costs of the remaining subactivity of District Law Enforcement, "Secretarial and clerical" ($2,545,594), were assigned to programs or subprograms by using the method employed to apportion costs of the subactivity, "Command supervision." The breakdown of costs of secretarial and clerical support to programs or subprograms are as follows:

Program/subprogram	*Amount*
Prevention	$819,611
Reaction	115,225
Followup	183,174
Public peace	184,233
Quasi-criminal	198,250
Traffic	52,598
Public service—emergency	121,701
Public service—specialized	509,824
Public service—other	92,047
Public relations	142,797
Support	126,134
Total	2,545,594

The overall picture of this final conversion from a line-item budget to the Resource Analysis Budget for command supervision of district law enforcement is shown in Table B-1.

Administration: Patrol

A cost breakdown of the organizational activity "Administration-patrol" was accomplished by identifying the number of Patrol Division personnel assigned, by sub-activity, to each program or subprogram. These totals were converted to percentages that were used to allocate the $750,923 cost of the activity. The results are shown below:

Program/subprogram	*Amount*
Prevention	$275,439
Reaction	31,689
Followup	66,606
Public peace	68,108
Quasi-criminal	53,916
Traffic	17,046
Public service—emergency	34,017
Public service—specialized	61,576
Public service—other	28,085
Public relations	46,182
Support	68,259

Prevention and Juvenile

Both organizational activities labeled "Administration-crime prevention" and "Prevention of crimes by juveniles" were examined concurrently. The Youth Division estimated its efforts as shown.

Subactivity	Percent of effort	Program/subprogram
Agency and court liaison	100	Followup.
Providing school patrol	100	Public service—specialized.
Other youth services	25	Social and economic conditions.
	25	Prevention.
	50	Followup.

These percentages were converted into costs which were allocated to programs or subprograms as follows:

Subactivity	Cost	Program/subprogram
Agency and court liaison	$102,048	Followup.
Providing school patrol	549,000	Public service—specialized.
Other youth services	2,756,907	Social and economic conditions ($689,227); prevention ($689,227); followup ($1,378,453).

Based upon the personnel strength assigned to each sub-activity, the cost of "Administration—crime prevention, supervisory and clerical" ($359,480) was apportioned to programs or subprograms as shown:

Program/subprogram	*Amount*
Social and economic conditions	$71,177
Prevention	71,177
Followup	150,981
Public service—specialized	56,691
Public service—other	9,454

(Because the Youth Division supervises the organizational activity budgeted as "Inspection of entertainment exhibitions," a portion of the cost, $9,454, must also be charged to the sub-program "Public Service—other" in the listing above.)

Costs of the sub-activity, "Prevention of crimes by juveniles—supervision," ($708,516) were allocated to programs or sub-programs based upon the assigned personnel strengths, as shown below.

Program/subprogram	*Amount*
Social and economic conditions	$147,726
Prevention	147,726
Followup	295,380
Public service—specialized	117,684

Administration—Traffic and Safety

Costs of the organizational activity, "Administration—Traffic Direction and Safety" ($381,055), were allocated to the following programs or subprograms based on the nature of activity:

Subactivity	Costs	Program/subprogram
Administration	$166,927	Traffic.
Safety education and training	163,824	Public service—specialized.
Operations	50,304	Traffic.

Costs of the organizational activity, "Conducting Traffic Investigations" ($632,542), were allocated to programs or subprograms, by sub-activity, as follows:

Subactivity	Costs	Program/subprogram
Investigating hit and run cases	$358,752	Followup.
Public passenger vehicle unit	237,790	Traffic.
Serving traffic warrants	36,000	Do.

Field Services Adm.

The method used to allocate portions of the total cost of the organizational activity, "Administration—Field Services" ($274,544), was to total all costs of supervision relating to the divisions of the Bureau of Field Services, and then convert these costs to percentages. The percentages were then used to allocate the costs to programs or subprograms as follows:

Program/subprogram	*Amount*
Social and economic conditions	$4,618
Prevention	69,385
Reaction	8,988
Followup	48,561
Public peace	14,657
Quasi-criminal	15,265
Traffic	34,817
Public service—emergency	9,375
Public service—specialized	41,233
Public service—other	7,273
Community relations	467
Human relations	221
Public relations	11,203
Support	10,481

Supervisory costs for the large Bureau of Field Services, sub-activity "Administration—Field Services," and their allocation among programs of the Resource Analysis Budget are shown in Table B-2.

Table B-2

Allocation of Costs for Administration—Field Services

Activity or subactivity	Social and economic conditions	Prevention	Reaction	Followup	Public peace	Quasi-criminal	Traffic
Administration/patrol		$275,339	$31,689	$66,606	$68,108	$53,916	$17,046
District law enforcement—command supervision		2,750,269	393,286	612,477	616,639	665,371	179,466
Patrolling by task force—supervisory		26,969		8,751	6,907		
Administration/crime detection—supervisory				310,877			
Area crime detection—supervisory				845,458			
Administration/crime prevention—supervisory	$71,177	71,177		150,981			
Prevention of crimes by juveniles—supervisory	147,726	147,726		295,380			
Administration/traffic—supervisory							166,927
Area traffic enforcement—supervisory							1,278,614
Community services division—supervisory							
Aggregate cost	$218,480	$3,271,480	$424,975	$2,290,530	$691,654	$719,287	$1,642,053
Percent of aggregate costs	1.67	25.09	3.25	17.56	5.30	5.52	12.59
Proportionate amount costed	$4,618	$69,385	$8,988	$48,561	$14,657	$15,265	$34,817

Table B-2 (Continued)

Activity or subactivity	Public service—emergency	Public service—specialized	Public service—other	Community relations	Human relations	Public relations	Support	Total costs of subactivity
Administration/patrol	$34,017	$61,576	$28,085	....	....	$46,132	$68,259	$750,923
District law enforcement—command supervision	408,627	1,705,326	305,458	....	....	477,897	423,950	8,538,766
Patrolling by task force—supervisory		1,089	....	....	....	....	....	43,716
Administration/crime detection—supervisory	....	....	....	....	....	....	....	310,877
Area crime detection—supervisory	....	....	....	....	....	....	....	845,458
Administration/crime prevention—supervisory		56,691	9,454	....	....	....	....	359,480
Prevention of crimes by juveniles—supervisory		117,684	....	....	....	....	....	708,516
Administration/traffic—supervisory	....	....	....	....	....	....	....	166,927
Area traffic enforcement—supervisory	....	....	....	....	....	....	....	1,278,614
Community services division—supervisory	....	....	....	$25,304	$10,335	....	....	35,639
Aggregate cost	$442,644	$1,942,366	$342,997	$25,304	$10,335	$524,079	$492,209	$13,038,916
Percent of total aggregate costs	3.39	14.91	2.63	.17	.08	4.05	3.79	100.00
Proportionate amount costed	$9,375	$41,233	$7,273	$467	$221	$11,203	$10,481	....

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