R-593-HUD/RC

February 1971

AIDS TO DECISIONMAKING IN POLICE PATROL

James S. Kakalik and Sorrel Wildhorn

A Report prepared for

DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT

Rand
SANTA MONICA, CA 90406

This research was supported by the Department of Housing and Urban Development under Contract No. H-1056. Views or conclusions contained in this study should not be interpreted as representing the official opinion or policy of Rand or of the Department of Housing and Urban Development.

R-593-HUD/RC

February 1971

AIDS TO DECISIONMAKING IN POLICE PATROL

James S. Kakalik and Sorrel Wildhorn

A Report prepared for

DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT

Rand
SANTA MONICA, CA 90406

PREFACE

This report contains the results of a five-month study of police patrol which was conducted as part of a broader study on the allocation and deployment of municipal services. Major financial support was provided by the U.S. Department of Housing and Urban Development. Part of the study, in particular the statistical analysis of crime, police resources, and demographic data, was supported by a grant from The Rand Corporation.

The study includes a description and comparison of the current allocation of police patrol resources in six major police jurisdictions; a statistical analysis of crime, police resources, and demographic data in several cities; a discussion and recommendations regarding criteria for evaluating the effectiveness and equity of the deployment of police patrol services; a description of the state of the art of patrol allocation methods, with recommendations for change in current methods; and an identification of some important problem areas and knowledge deficiencies that might benefit from research and experimentation.

A companion volume, R-594-HUD/RC, contains the detailed responses elicited by questionnaire and personal visits to the six participating police departments. They are: Los Angeles City, Los Angeles County, Phoenix, St. Louis, and two major municipal police departments who requested they not be identified. Information is provided on costs, manpower usage and deployment, patrol tactics and operations, deployment methodology, the demand for patrol services, data and computer systems, research projects, and the police view of important problems. For the two major city police departments who asked not to be identified, numerical responses to certain indicated questions have been modified by a constant multiplier to obscure the identity of the two cities.

The intended audiences for this report are twofold: local government decisionmakers (police, city, and county officials) concerned with police planning; and private foundations plus local, state, and federal government officials charged with the responsibility for sponsoring research, development, and demonstration projects in law enforcement. Thus, although the focus of the discussion is both descriptive and analytical, the technical and mathematical details have been deliberately suppressed, where possible.

An abridgment of this report, R-593-HUD/RC (Abridged), is also available which contains a summary of the major findings of the study.

SUMMARY

Over the past several years, reported crime and the fear of crime have increased sharply in the United States. These phenomena, together with others, have focused attention on the police and their role in society. As a nation, we spend annually over $5 billion on the criminal justice system. More than 40,000 police agencies account for over $2.5 billion, greater than 50 percent of the total. Well over $1.0 billion is allocated to police patrol—the heart of police law enforcement.[1]

With increasing demands on limited local government funds, there is a growing need for effective aids to decisionmaking in determining:

- Proper patrol force strength.
- Equitable and effective distribution of patrol services by police district and tour of duty.
- Effective operational policies and tactics for police patrol.

The goal of this study is to provide a coherent, unified overview of certain decisionmaking aids currently and potentially available to police in addressing these three major patrol issues. In pursuing such a goal our objectives were threefold: to synthesize aspects of previous work relevant to the three basic patrol issues posed; to build upon it; and to indicate clearly the research and experimentation still needed to bridge basic knowledge gaps.

Prior work by the Presidential Crime Commission in 1966-1967 structured in a general way many of the problems confronting decisionmakers in the criminal justice system, thereby providing a framework for much of the research and experimentation currently in progress. Several operationally oriented studies have recently appeared which demonstrate the feasibility and utility of quantitative analysis in police patrol decisionmaking.[2]

[1] These figures are from *The Challenge of Crime in a Free Society*, a report by the President's Commission on Law Enforcement and Administration of Justice, U.S. Government Printing Office, Washington, D.C., February 1967.

[2] In particular, see the following: *Task Force Report: The Police* and *Task Force Report: Science and Technology* of the President's Commission on Law Enforcement and Administration of Justice, U.S. Government Printing Office, Washington, D.C., 1967; A. Blumstein, *A National Program of Research, Development, Test, and Evaluation on Law Enforcement*, Institute for Defense Analyses, November 1968 (prepared for Law Enforcement Assistance Administration, U.S. Department of Justice); *Allocation of Patrol Manpower Resources in the St. Louis Police Department*, Vols. I and II, conducted under Grant No.

With this work as a background, then, our research plan devolved into four tasks: (1) to provide a conceptual framework and systematic discussion of evaluation criteria relevant to the three patrol issues; (2) to acquire, analyze, and compare data from several major police jurisdictions on demands for police service, current resource allocation, allocation methods and criteria currently employed, operational policies, and patrol organization; (3) to describe currently feasible improvements in certain decisionmaking aids; and (4) to discuss the basic knowledge deficiencies (related to these patrol issues) that could benefit from research and experimentation.

CRITERIA FOR EVALUATING POLICE PATROL PROGRAMS

Fundamental to all questions of resource allocation is the careful selection of appropriate evaluation criteria. Previous work has not dealt comprehensively and systematically with this topic in relation to the three basic patrol issues. Relevant factors to consider in choosing criteria include: measurability, statistical variability, policy sensitivity, degree of acceptability to the police and the public, and degree to which program outputs, rather than resource inputs, are measured. Criteria selected should measure the effectiveness, efficiency, and equity of the level and distribution of patrol resources and services. Furthermore, they should enable all major functions of patrol to be evaluated, namely, apprehension of suspects, crime prevention and deterrence, and the patrol's accessibility and responsiveness to calls for service.

Currently, systematic evaluation of police patrol operations is frequently lacking. While police departments collect extensive data on each crime, they often fail to collect and use data that are relevant for the management and evaluation of patrol operations. In our study, we found that criteria currently employed in different jurisdictions vary widely, and include "command discretion," simple resource input measures, conglomerate hazard ratings, and the percentage of calls for service that cannot be immediately dispatched to a free patrol car.

Because of the complexity and multiplicity of functions which the police patrol performs, no single criterion appears adequate for evaluation purposes. Rather, it would be preferable for police planners to employ *a set of criteria,* with each criterion receiving *individual* attention. In employing sets of criteria, the method used should guarantee, at least, that minimally acceptable levels of patrol performance are maintained for *each* criterion. The improved methods proposed for addressing resource allocation issues can, in fact, handle several criteria simultaneously, guaranteeing that minimally acceptable levels of patrol performance are maintained for each. Thus, it is not appropriate to consolidate a set of criteria into one conglomerate measure by taking a weighted summation of the values of the

39 for the Office of Law Enforcement Assistance, U.S. Department of Justice, July 1966; and R. C. Larson, *Models for the Allocation of Urban Police Patrol Forces,* Technical Report 44, Operations Research Center, Massachusetts Institute of Technology, November 1969. Unpublished work by The Rand Corporation for the New York City Police Department has influenced the structure and content of this report.

individual criteria. All too often this latter practice may result in one or two criteria unintentionally dominating all others.

An ideal set of criteria might reflect true crime rate,[3] true victimization rate,[4] total social and economic impacts of crime, number of crimes prevented and deterred, plus criminal and public attitudes in relation to alternative police patrol programs. Unfortunately, none of these quantities can be easily and accurately measured at present. Consequently, proxy measures of effect must be employed.

The actual set of criteria employed should depend on the circumstances of the individual department, the decision issue, and the alternative patrol programs to be evaluated. Despite the difficulties of generalizing, we suggest that the following set of criteria may have wide applicability.

A Preferred Set of Criteria for Evaluating Police Patrol Programs

1. Patrol arrest rate,[5] by crime category.
2. Charging rate,[5] by crime category, with an indication of whether the patrol arrest occurred in response to a call or during preventive patrol.
3. Reported victimization rate,[4] by crime category and citizen group.
4. Reported crime, by crime category.
5. Percentage of citizens satisfied with various aspects of patrol service.
6. Elapsed time from a call for police service until arrival of a patrol car; measured by both the average time and the percentage of response times exceeding a specified time t.
7. Preventive patrol frequency.[6]
8. Hours of preventive patrol per "suppressible crime."[6]
9. Resources expended: total patrol budget, total patrol man-hours and total car-hours, plus a breakdown of each total into percentage allocated to each patrol function.

Average citywide values of the first eight criteria above could be used to judge effectiveness, while comparisons of values of criteria disaggregated by time, place, and population group could be used to judge how equitably patrol services are distributed. The relationship between resources expended (criterion 9) and the effectiveness achieved would measure the efficiency of patrol operations.

[3] Since the publication of the President's Crime Commission report, the fact that not all true (actual) crime is reported is now well known. For example, a victimization survey estimated that the actual number of forcible rapes were more than 3½ times the reported number, that the actual number of aggravated assaults were twice the reported number, and that the actual number of robberies were 50 percent greater than the reported number.

[4] True victimization rate is the actual number of crimes (in a given category or set of categories) per thousand population. See Glossary.

[5] See Glossary.

[6] See Glossary.

POLICE PATROL PROGRAMS IN SEVERAL CITIES

Systematic discussions of evaluation criteria and the methodological aspects of patrol resource allocation are of only limited value without real data. Existing data sources were very limited. We found only two sources containing data on a large sample of cities. One is the well-known annual FBI reports of citywide serious crime rates. The other is a survey of 37 large municipal police departments conducted annually by the Kansas City Police Department. This survey contains general administrative data, including police department budgets, police strength, manning by rank, function, and shift, salary, fringe benefits, and some organizational data.

But to accomplish the purposes of this study, it was necessary to collect additional detailed information from several cities. The data included: crime, calls for service and patrol deployment (by police district and tour of duty, as well as for the city as a whole); trends over time of demands for police service and patrol manning; patrol organization and operational policies; the internal police planning organizations; the uses of data and computers in police departments; criteria and methods of allocating patrol resources employed by police departments; and so on.

Limited resources restricted data gathering to six major police jurisdictions, because it was necessary to elicit responses both by questionnaire and by personal visits. The six participating departments were those of Los Angeles City, Los Angeles County, St. Louis, Phoenix, and two other cities that requested that they not be identified. The departments ranged in size from medium to large, employed a wide variety of patrol allocation techniques (including some advanced techniques), and the sample included older and densely populated, as well as newer and more sparsely populated cities.

A second report, R-594-HUD/RC, contains detailed survey responses from the six participating police departments.

An important, but not surprising, finding from the six-city survey is that most measures of patrol workload, police input, and demand (expressed in per capita, per policeman, per patrol car, or per square mile terms) vary widely among the six cities. For example, annual Part I crimes[7] per capita vary from 0.03 to 0.14; police budget per capita varies between $13 and $85; uniformed patrol strength per thousand residents varies between 1.0 and 2.5; patrol cars on the street per shift per square mile vary between 0.045 and 2.7; calls for service per patrol car per shift vary between 2.5 and 11.5; annual Part I crimes per uniformed patrolman vary between 26 and 70; and annual Part I plus Part II arrests per uniformed patrolman vary between 22 and 79.

Viewing the trends over the decade of the sixties, we judge that in the six cities surveyed *increases in police strength or police per capita have not kept pace with increases in reported crime per capita, although they have outpaced population change.* For example, in the six cities surveyed, reported Part I crime per capita has grown at least 50 percent in two cities and as much as 180 percent in two others, whereas uniformed patrolmen per capita have only increased by 12 to 43 percent.

[7] See Glossary.

Workload per patrolman has grown, too, but not as rapidly as reported crime per capita. Calls for service per patrolman increased by 30 to 45 percent and reported crimes per patrolman increased by 35 to 160 percent. Generally speaking, over the ten-year period, the relative disparities between growth in demand for police services, and growth in police resources and workloads, appear to be least in Los Angeles (City and County), and greatest in St. Louis, City "X," and City "Y."

As to organizational and operational features of police patrol, the six-city survey revealed that there are more similarities than dissimilarities among departments. All six patrol organizations exhibit similar geographical command hierarchies; decisions on basic beat assignments and reassignments during shifts of patrol resources are generally the responsibility of district commanders; dispatching operations are generally centralized; and most departments operate under an informal, rather than formal, priority policy in responding to calls for service from the public.

All the police departments surveyed operate an internal planning and research unit. The extent of the unit's influence in the department and the decisions which it affects vary from department to department. All utilize outside consultants for a variety of purposes; most frequently outside consultants study proposed organizational changes, design information, command-control, and management systems, as well as work on resource allocation and workload prediction schemes. The internal planning unit usually monitors the activities of outside consultants.

The President's Crime Commission recommended that all large police departments assemble a capable, in-house staff to do planning, research, and experimentation. We feel that this planning staff should include at least one competent *civilian* planner who is highly trained and experienced in operations research, cost-benefit analysis, and the use of computers. Since the overwhelming majority of departments now do not have sworn officers on the force with such qualifications, and since it is unlikely that lateral entry into the sworn force of such personnel will come about in the near future, such a planner usually must be a civilian. In addition to conducting in-house planning and research, facilitating the implementation of innovations within the department, a key in-house civilian planner could interpret police policy and needs (as articulated by top police management) in terms relevant to the consultants. Additionally, he could be invaluable in guiding, evaluating, and interpreting the work of outside consultants. To attract and retain such key civilian planning personnel, police departments should recruit from the graduate schools of better universities and from private industry and research organizations; they must pay competitive rates; and most importantly, they must provide the planner with ready access to the police chief.

All six departments use the computer as an internal management information and retrieval system for one or more of the following: arrest, crime, incident, narcotics, clearance, personnel, and traffic reporting. In addition, some departments use or plan to use the computer as an integral part of *operational* information and/or command-control systems such as dispatching, wants and warrant searches, stolen vehicles files, and modus operandi (M.O.) files. However, *most departments surveyed did not collect certain management data that would be extremely useful in providing relevant inputs into the major patrol allocation and tactical decisions* *posed above.* For example, of the data necessary to estimate values for the preferred evaluation criteria discussed previously, only reported crime data are available in all cities, although reported victimization rate can be estimated from available data by crime category, but not by citizen group. Most departments simply do not know how responsive their patrol force is either in terms of various time delay components or in terms of the average percentage of calls for which a patrol car cannot be dispatched immediately. Nor do they know the distribution of preventive patrol frequency and preventive patrol per suppressible crime, the patrol arrest rate, the public's degree of satisfaction with police patrol service, or various measures of patrol resource expenditure.

We suggest that *police departments should institute a systematic and reliable information system to collect these data.* Only some data need be collected on a routine basis; others need only be sampled intermittently, in all districts, by hour, day, week, etc.

Statistical analyses can be useful in attempting to estimate to what extent patrol resources affect crime rate (and vice versa) and to what extent *other* factors affect crime rate. Applied to citywide data from several cities, such analyses are relevant at the patrol force level; applied to data disaggregated by police district for a single city, such analyses are relevant to allocating patrol resources by geography. In any event, as the Crime Commission noted, statistical analyses should precede controlled experiments aimed at a final determination of the effect of police manning level on crime.

Illustrative analyses of the six-city sample data revealed statistically significant relationships among several pairs of variables, such as calls for service and population, calls for service and police strength, density of calls for service and patrol density, Part I crimes per capita, and patrol strength per capita. However, little can be concluded from these analyses because of the small sample of cities employed. Mostly, this work provided guidance for the analysis of a 30-city subsample from the 37-city survey of police departments conducted by the Kansas City Police Department.

Analysis of the 30-city data produced formulas which would relate current police manpower levels to reported Index crime,[8] population, and other community socioeconomic factors. We also sought formulas that relate reported Index crime to police manpower levels, population, and so on. A successful formula for police manpower level, for example, is one in which the actual manpower level and the manpower level calculated by the formula are approximately the same.

For example, in analyzing 1968 crime and police manpower data for this 30-city sample (for which data we had no socioeconomic data other than population and area), we sought a formula to describe current police per capita in terms of reported Index crimes per capita and population density. This formulation was reasonably successful. This and other formulations are described in the report. In analyzing 1960 data for the 30-city sample, we postulated more complex relationships, attempting to include possible effects on crime and police strength of demo-

[8] See Glossary.

graphic measures, such as percentages of poor, those in the 15-to-29-year-old group, nonwhites, and a mobility variable. The formulas for crime *per capita* or police strength *per capita* were relatively unsuccessful, whether or not such demographic variables were included. Limited success was achieved with formulas for *absolute* measures of crime and police strength (such as number of Index crimes and police manning levels), but adding the demographic variables to the formulas did not result in any significant improvement. This is not to say that socioeconomic variables are not related to crime and police strength, but rather that the 1960 data did not reveal strong relationships. The basic fact was that 1960 Index crimes per capita were uncorrelated with nearly every other variable. We cannot explain this fact other than to speculate that crime reporting practices, procedures, and standards may have been much less uniform in 1960 than they are currently.

Although our preliminary illustrative statistical analysis shows mixed results, we believe it worthwhile to invest further resources in analysis such as this. Previous work in this area has been almost nonexistent. It would be advantageous, however, to have data for several years (perhaps disaggregated by police district) for one city as well as cross-sectional data (that is, data for a specific year for several cities). It would then be possible to improve the formulas by including *rates of change* and time-lag effects in the variables. Data should be sought which include, in addition to crime, police strength, and demographic variables, other factors which may be relevant. These might include other criminal justice variables, such as recidivism rates, sentencing practices, and effectiveness of correctional programs, as well as data on the public's attitudes on crime and law enforcement. The latter should affect the kinds and levels of services provided by the police, and the relative emphasis given to enforcement of various criminal statutes, thereby influencing the level and deployment of patrol strength.

PATROL ALLOCATION METHODS

To be of maximum possible value, allocation methods should employ data that can be readily obtained; allocate on the basis of predicted future conditions rather than past conditions; use several evaluation criteria, so that several policy-relevant aspects of each proposed manpower allocation can be adequately evaluated; focus separately on each criterion rather than on a conglomerate measure; provide the capability of allocating and deploying resources by day, shift, and district rather than by district only; be relevant to decisions on force size and deployment for preventive patrol as well as for response to calls for service; and provide the capability of evaluating alternative operational policies, tactics, and command-control hardware.

Methods Currently in Use

Command discretion and judgment play a role in all decisions involving patrol force level, allocation, and techniques. However, the character of quantitative aids, and the manner of using such aids to decisionmaking, varied significantly among the departments surveyed.

"Hazard formulas" are widely used for allocating manpower by time and geography. This method takes all factors thought relevant to determining the need for patrol services, weights each factor by its importance, and adds to arrive at a single hazard number. Men are then distributed in proportion to the relative hazard in an area. The hazard formula method is unsatisfactory for several reasons. The additive weighted combination of the many hazard factors can reflect neither the highly complex interactions among the factors nor focus individual attention on any single factor. As typically used, hazard formulas reflect past conditions for a district rather than predicted future conditions for day, shift, and district. More importantly, existing hazard formulas do not relate meaningful measures of effectiveness to operational policies. Also, hazard formulas are not relevant to determining the total size of the patrol force required to satisfy certain service-level criteria.

In Phoenix, the hazard formula concept is employed in an innovative and helpful manner. The basic hazard (elapsed time) is defined as the delay plus travel plus service times for all responses to calls during a given time period in a given place. The three constructive innovations are (1) the use of predicted calls rather than calls actually experienced in the past, (2) the use of elapsed time rather than just volume of calls, and (3) an allocation simultaneously by day, shift, and district rather than by district alone. However, preventive aspects of patrol are not addressed. Also, delay, travel, and service times for *all* types of calls are given equal weight.

The most advanced operational method of patrol force deployment currently in use has been developed and applied in St. Louis. In their method, demand for police services is predicted by hour and geographic area. A simple mathematical technique is then used to estimate the number of patrol cars needed to immediately answer, without dispatching delay, 85 percent of the predicted incoming calls for service in each geographic area by day and four-hour time periods. The remainder of the patrol force is assigned to preventive patrol. The St. Louis efforts are a commendable beginning toward improving techniques of police patrol deployment. However, their deployment methods are limited in that the sole criterion used in the mathematical technique to determine the required number of response cars (i.e., the split of the patrol force into response and preventive units) is the fraction of calls that cannot be answered immediately by a response car. Requirements for preventive patrol are not explicitly considered when assigning cars and the question of the relative value of a car on response and on preventive assignments is not addressed. Also, certain policy issues such as the appropriate size of the mobile patrol force cannot be addressed. Based on the St. Louis method, the IBM Corporation has developed a computer program (LEMRAS) which it will lease to police departments.

The need for police services varies significantly by day of week, shift, and geographic area. Flexibility is best maintained if deployment decisions are made by time and area simultaneously. (This often gives rise to deployments significantly different from current ones.) Currently, the need for police services exhibits much greater variation, by time period and geographic area within a city, than is exhibited by the number of patrolmen actually deployed.

Dramatically different deployments can result when criteria are changed. We present several examples. In one case cited, the difference between the current deployments to police districts in one city, and those that will result when that city implements its new deployment method, was estimated to average 30 percent over all shifts and districts. There was an estimated maximum difference of 120 percent for one shift in one district.

Improved Methods

No city is using all of the available mathematical tools. This does not seem to be because of a decision to avoid their use, nor because of recurring costs of using those techniques, but rather because a "ready to use" package is not currently available, and because the police rarely have any employees who have sufficient relevant (mathematical) training to understand, interpret, use, and communicate such techniques.

Two patrol allocation methods, mathematically feasible, but different from any now in use, possess logical advantages over those currently in use. They combine the more desirable attributes of existing methods and are sufficiently flexible to meet the needs of a variety of police jurisdictions. *We suggest that such approaches be fully developed, tested, and applied.*

The first approach has primary relevance to two of the three patrol issues posed, namely, patrol force strength and deployment of a specified force by time and geography. The steps in this approach are:

1. *Prediction of the incidence of crime and calls for service,* by type, for each geographic area and desired time period. These would be relevant to both decisions on current deployments and the number of additional patrolmen needed in the near future.
2. *Specification of a set of criteria and the desired target levels of performance* for each such criterion. Any set of criteria which can be analytically related to patrol manpower can be utilized.
3. *Estimation of the number of men required to achieve specified target levels of performance.* Analytic methods are available for relating number and deployment of patrolmen to measures such as average or maximum response time, percent of calls not immediately dispatchable, preventive patrol frequency, hours available for preventive patrol, per suppressible crime, or probability of on-scene arrest. Unfortunately, basic knowledge is not available for relating manpower to arrests, crime, and public order. That basic knowledge deficiency is the weakest element of every available method. However, relating manpower to responsiveness and patrol coverage, as this suggested approach would, is an important step forward.
4. *Allocation of patrol manpower.* Quantitative techniques known as mathematical programming are available to specify the deployment of a given

patrol force, by time and place, to achieve certain specified levels of service in terms of each measure. A particular overall patrol force level might not provide sufficient manpower to meet minimum acceptable service levels for all criteria. In that event, the method can be employed using various potential patrol force levels to determine the minimum force level required to meet all minimum service levels. In this way, this approach also can be used to address the patrol force strength issue.[9]

This approach, then, is more comprehensive than any of those presently in use, because it allocates on predicted demand for services, because it addresses the preventive as well as response functions of patrol, and because it employs several criteria simultaneously while striving to ensure that minimum levels of service are maintained for each criterion. One restricted version of this approach has been developed and is described in Chapter IV.

A second method involves the simulation of patrol activities on a computer and would be useful in situations where some critical part of the patrol operation cannot be mathematically analyzed in a manner useful for policymaking. The advantage of the simulation method comes from its ability to investigate the implications of rather complicated deployment strategies and tactics, operational policies, and command-control systems by use of a computer, before undertaking expensive field tests.

For example, the simulation method can evaluate various priority and dispatching rules in responding to calls; these can range from rules on "stacking" calls and assigning cars from other areas to relocation of cars to perform preventive patrol. Also, the effectiveness of certain technological innovations, such as alternative car-locator systems, can be evaluated.

AREAS OF NEEDED RESEARCH AND EXPERIMENTATION

There are significant knowledge gaps which make it impossible to allocate, as rationally as should be, the more than $1 billion devoted annually to police patrol programs. Because of these knowledge gaps, police administrators currently must plan largely in terms of *input measures* (such as number of patrolmen on the street or number of patrol hours) although what they are trying to affect are *output measures* of police effectiveness (such as true crime rate, apprehension rate, and speed and quality of service in response to calls for service).

In identifying these knowledge deficiencies and areas of needed research on police patrol programs, we limit our attention to *resource allocation and use of police patrol forces.* Our suggestions are intended to supplement, in the area of resource allocation, those of the Police and Science and Technology Task Forces of the President's Crime Commission, as well as those of a subsequent U.S. Justice Department

[9] In addition, statistical analyses of the sort described previously can also be used in addressing the force level issue.

sponsored study of the nation's needs for research and experimentation on law enforcement and criminal justice.

We propose that research and experimentation be undertaken (1) *to identify the relationship between police preventive patrol activity and crime prevention, deterrence, and on-scene criminal apprehension;* (2) *to identify the quantitative and qualitative relationships between speed and type of police response, on the one hand, and crime rate, deterrence of crime, probability of on-scene apprehension, availability of witnesses, and the public's satisfaction with police patrol services, on the other hand;* (3) *to predict crime and the volume of calls for police services,* so that police can be recruited and deployed based on more accurate knowledge of the need for police service in each geographic area and time period. Finally, we suggest (4) that *improved methods for deploying patrol manpower,* which are described in Chapter IV of this report, *be tested experimentally, modified if indicated by test results, and implemented.*

SUMMARY OF POLICY-RELEVANT SUGGESTIONS

In attempting to provide a unified overview of certain decisionmaking aids in addressing three major police patrol issues, this study suggests that police departments:

1. Employ multiple criteria in decisionmaking. One preferred set is described in this study.
2. Develop, test, and apply improved methods in allocating patrol resources. Two such methods are described.
3. Undertake to collect certain management oriented data.
4. Hire competent, civilian planners to supplement police personnel in planning units and give them ready access to top police management.
5. Undertake long-term research and experimentation to bridge certain fundamental gaps in present knowledge regarding relationships between police resource inputs and police effectiveness.

ACKNOWLEDGMENTS

We received excellent cooperation from each of the six police jurisdictions that participated in the survey. In particular, we are grateful to the following people: Chief Edward Davis, and Lieutenant George Conroy, Noel Hanson, and Norman Smith of the Advanced Planning Division and Officer Pat Mercier of the Patrol Bureau, Los Angeles Police Department; Sheriff Peter Pitchess, Lieutenant Robert Galloway, and Sergeant Maher of the Research and Development Bureau, Los Angeles County Sheriff's Department; Chief Lawrence Wetzel, and Captain Robert Beck, Director of the Research and Development Bureau, Phoenix Police Department; Chief Eugene Camp, Dr. Nelson Heller of the Board of Police Commissioners staff, and Thomas McEwen, Director of the Resource Allocation Unit, St. Louis Metropolitan Police Department; and finally, the Chiefs of Police and Directors of Planning and Research for each of the two municipal Police Departments which requested anonymity.

The data from the Kansas City Police Department's annual survey of municipal Police Departments was especially helpful.

Finally, the assistance of several Rand colleagues is acknowledged: Roger Levien encouraged and supported the project; Harvey Averch and John Koehler were available as consultants for the statistical analysis; and Harvey Averch, Richard Larson, and Marvin Lavin offered helpful suggestions concerning an earlier version of this report.

CONTENTS

FIGURES

TABLES

Appendix Tables

GLOSSARY

This glossary defines some of the terms which the reader may find unfamiliar.

Index crime — The seven serious crimes used by the FBI in compiling their crime index. They are: murder and nonnegligent manslaughter, forcible rape, robbery, aggravated assault, burglary, larceny involving $50 and over, and auto theft.

Part I crime — As defined by the FBI, Part I offenses are the seven serious crimes comprising the Index crimes *plus:* negligent manslaughter, simple assault, and larceny involving less than $50.

Part II crime — As defined by the FBI, Part II offense classes comprise: other assaults, arson, forgery and counterfeiting, fraud, embezzlement, stolen property (buying, receiving, possessing), vandalism, weapons (carrying, possessing, etc.), prostitution and commercialized vice, other sex offenses, narcotic drug laws, gambling, offenses against the family and children, driving under the influence, liquor laws, drunkenness, disorderly conduct, vagrancy, and all other state or local offenses not included in Part I and above mentioned crimes.

Reported crime — The number of crimes (in a given category or group of categories) reported to the public and government agencies by the police.

True or actual crime — The number of *reported and unreported* crimes (in a given category or group of categories) actually committed.

Suppressible crime — Those types of crimes that may be significantly deterred or prevented by police patrol activity. While the actual types of crimes which are affected by patrol are not well understood, one possible categorization, used by the New York City Police Department, is all "outside" crimes. That is, crimes which occur on the street, or which could be detected by a patrolman from the street. These include, for example, most street muggings, but relatively few burglaries.

Crime or victimization rate — Number of crimes (in a given category) per year per thousand residents (in a given category). The categories of crime and residents will be specified by the context.

Victimization probability — The probability that a randomly selected citizen will be the victim of a crime within a year.

Arrest rate — The proportion of reported crimes (in a given category or group of categories) for which at least one suspect is arrested.

Charging rate — The proportion of reported crimes (in a given category or group of categories) for which at least one suspect is formally charged in the judiciary branch of the criminal justice apparatus.

Patrol frequency — The number of times a patrol car passes a randomly selected address per unit of time.

Input criterion — A criterion used to measure and evaluate resource inputs to a system.

Output criterion — A criterion used to measure and evaluate outputs or effects of a system.

Proxy criterion — A criterion used as a proxy measure of outputs of a system. It is usually used when true output measures are not available or not measurable.

I. INTRODUCTION

This nation spends over $5 billion annually on the criminal justice system. More than 40,000 police agencies account for over $2.5 billion, greater than 50 percent of the total. Well over $1.0 billion is allocated to police patrol—the heart of police law enforcement.[1] With increasing demands on limited local government funds, there is a growing need for effective aids to police patrol decisionmaking.

Our goal is to provide a coherent, unified overview of certain current and potential decisionmaking aids available to police in addressing three basic patrol issues:

- Overall patrol strength.
- Equitable, effective, and efficient deployment of patrol resources geographically and temporally.
- Effective patrol techniques and operational policies to be employed.

Our perceived role in pursuing the goal of this study is threefold: to synthesize aspects of previous studies relevant to the three basic patrol issues posed; to build upon them; and to indicate the research and experimentation still needed to bridge basic knowledge gaps.

By and large, previous work was either quite general and exhortative in nature or, when specific, was often narrowly focused. Both the Police Task Force and the Science and Technology Task Force of the President's Commission on Law Enforcement and Administration of Justice recommended that a variety of research and experimentation should be undertaken in the field of police operations and patrol allocation. In discussing police planning, research, and analysis, the Police Task Force suggested that crime trends be studied and that experimental projects be devised to test novel police techniques on a limited scale and under controlled conditions.[2] The Science and Technology Task Force recommended that police departments should undertake data collection and experimentation programs to de-

[1] *The Challenge of Crime in a Free Society*, a report by the President's Commission on Law Enforcement and Administration of Justice, U.S. Government Printing Office, Washington, D.C., February 1967.

[2] *Task Force Report: The Police*, the President's Commission on Law Enforcement and Administration of Justice, U.S. Government Printing Office, Washington, D.C., 1967, p. 49.

velop appropriate statistical procedures for manpower allocation.[3] It further suggested that the entire police command-control function, including many aspects of patrol operations, be subjected to basic reexamination, taking full account of new capabilities offered by computers and communication links. This review should consider questions of when, where, and how to use the patrol force, how response time can be reduced, the extent to which preventive patrol deters crime, how forces should be allocated by time and geography, optimum patrol tactics, and the relationship between speed of response and certainty of apprehension.[4] In addition to recognizing the need for such research and experimentation, the Science and Technology Task Force conducted several preliminary studies relevant to some of the basic issues posed in our study. These included a study of communications, crimes, and arrests in one metropolitan police department which, among other things, attempted to estimate the relationship between speed of response and probability of apprehension; an illustrative program budget for a city police force; and a statistical analysis to predict the number of reported serious crimes in each of a metropolitan police department's divisions as a function of the number of patrol officers assigned to a division, in order to estimate the relationship between change in crime and change in manning level.

A more recent report, outlining a suggested national program of research and experimentation in law enforcement and criminal justice, recommended similar undertakings.[5] Because of gaps in present research, among the high-priority research projects suggested were the following: analysis and experimentation with preventive patrol strategies and techniques; studies of factors operative in deterring crime; design of improved command-control systems; and improving the allocation of police resources by time, place, and function.

Our overview of decisionmaking aids begins with the development of a conceptual framework of evaluation criteria relevant to the three patrol issues posed (Chapter II). This is fundamental and necessary in any systematic discussion and examination of resource allocation questions.[6]

But systematic discussions of evaluation criteria and methods for allocating patrol resources are of only limited value without real data. Thus, we needed to examine and compare data from several cities on current patrol strength, patrol deployment, patrol tactics, organization, and operational policies, crime and demands for service, and on current criteria, methods, and quantitative aids used to allocate such resources. Existing data sources were found to be extremely limited. In fact, we located only two bodies of data for a large sample of cities. One is a survey of municipal police departments, conducted annually by the Kansas City Police

[3] *The Challenge of Crime in a Free Society*, p. 257.

[4] *Task Force Report: Science and Technology*, the President's Commission on Law Enforcement and Administration of Justice, U.S. Government Printing Office, Washington, D.C., 1967, p. 25.

[5] A. Blumstein, *A National Program of Research, Development, Test, and Evaluation on Law Enforcement and Criminal Justice*, Institute for Defense Analyses, November 1968.

[6] Neither the sources quoted previously nor earlier publications dealt comprehensively with evaluation criteria for use in patrol resource allocation. Examples of major earlier sources are O. W. Wilson, *Police Administration*, McGraw-Hill, Second Edition, 1963, and S. G. Chapman, *Police Patrol Readings*, Charles C. Thomas, Springfield, Illinois, 1964.

Department, of the 37 cities whose 1960 Census populations were between 300,000 and 1,000,000.[7] This survey contains general administrative data, including police department budgets, police strength, manning by rank, function and shift, salary, fringe benefits, and some organizational data. The other is the annual FBI reports of citywide serious crime rates, by crime type, for U.S. cities.[8]

To help accomplish the purposes of this study, we sought additional information from several cities, including data on demands for police service, such as crime and calls for service, by police district and tour of duty, as well as for the city as a whole; on deployment of patrol manning and patrol cars by police district and tour of duty; on trends over time of demands for police service and patrol deployment; on patrol organization and operational policies; on the internal police planning organization; on the uses of data and computers in police departments; on criteria and methods of allocating patrol resources employed by police departments; and so on.

Limited resources restricted our data to six cities. These cities were selected with the following criteria in mind: police department size should range from medium to large; the sample should include departments which employ a variety of patrol allocation methods, criteria, and operational policies; the sample should also include police departments using more advanced methods and techniques; the sample should include both older and densely populated as well as newer and more sparsely populated cities. The participating police departments selected were those of Los Angeles City, Los Angeles County, St. Louis, Phoenix, and two cities which requested that they not be identified.

Detailed questionnaires were prepared and submitted. In addition, each department was visited at least once by the authors in order to discuss the meaning and intent of the questionnaire and to synthesize detailed data into a useful form, as well as to gather additional information where available. The detailed responses to the survey questionnaire appear in R-594-HUD/RC. In presenting and discussing the data and responses for the two cities which asked not to be identified, we have attempted to preserve their anonymity by altering the data in some consistent way, or by presenting the original data in a form where recognition is difficult.

In Chapter III, information from the six-city sample and from the larger sample of cities comprising the Kansas City Police Department survey is used to make observations, comparisons, and analyses pertaining to two of the three patrol issues posed, namely, the patrol force strength and patrol organization, tactics, and operational policies. The six-city descriptions and comparisons are noteworthy, since data are presented that were not heretofore available.

Chapter IV focuses on the methodological state of the art in addressing all three patrol issues, with particular emphasis on the deployment of patrol resources by time and geography. Using data from the six-city sample, we describe, compare, and illustrate the major methods currently in use. In addition, two methods recently

[7] *Annual Survey of Municipal Police Departments*, Kansas City Police Department, Kansas City, Mo. (published annually).

[8] *Crime in the United States*, Uniform Crime Reports for the United States, Federal Bureau of Investigation, U.S. Department of Justice (published annually).

developed by R. C. Larson are described. A promising new approach, which synthesizes and modestly extends certain existing methods, is depicted. This new approach is currently applicable if patrol manpower levels and deployment are evaluated in terms of criteria such as response time to calls for service and frequency of preventive patrol.

If better evaluation criteria, such as charging rate, reported or true crime, and victimization rate are to be used, the new approach is not applicable at this time because, like all known analytical aids to patrol decisionmaking, it suffers from several basic knowledge deficiencies. One important unknown already mentioned is the effect of police manning level, patrol tactics, and operational policies on crime. Another is the relationship between response speed and probability of apprehension. Still another is the value of reducing response speed in answering the public's calls for service which are noncrime related. The data, research, and experimentation still needed to bridge these gaps in knowledge are discussed in Chapter V.

II. PATROL EVALUATION CRITERIA

A FRAMEWORK FOR DISCUSSION

The Functions of Patrol

The major functions and activities of all police patrol forces are (1) to prevent and deter crime, (2) to apprehend criminals, (3) to respond to calls for assistance from the public, and (4) to regulate certain noncriminal activities such as traffic. Prevention and deterrence of crime involve a number of activities such as preventive patrol of an area, door and window checks of business and residential premises, detection of crimes in progress, and apprehension of suspects near the crime scene. Uniformed patrolmen respond to calls for assistance involving alleged past crimes or crimes in progress, and a variety of other situations such as family disputes, disorderly or noisy groups, sick or injured persons who are in need of an ambulance, detection of suspicious persons or prowlers, fire alarms, and so on. Apprehension of suspects by patrolmen usually occurs near the scene of the crime. The demands placed on police patrol are diverse, including many activities which are not crime related.

As indicated in R-594-HUD/RC, the traffic control function is performed by the patrol bureau in some police departments. Crowd control is usually a function of the patrol bureau, but this activity occurs relatively infrequently. Preliminary investigation of certain crimes is performed by patrolmen in some departments. Processing and transporting arrestees and appearing in court consumes a significant fraction of a patrolman's time. And, depending on historical precedent and other factors, most patrol bureaus perform some specialized functions such as licensing cabarets and taxi drivers, operating harbor patrols, guarding special fixed posts, taking population census, and so on.

Our discussion of criteria for allocating patrol resources will focus primarily on three major functions of patrol, namely, deterring and preventing crime, apprehending suspects, and responding to calls for assistance. These functions account for most of the daily workload.

Patrol Program Decisions

A general discussion of criteria is meaningful only insofar as the use to which such criteria are put is made explicit. Specifically, our discussion of criteria is relevant to the following decisions and operational problems confronting patrol administrators:

(1) Determining the overall patrol force strength.[1]
(2) Allocating a given patrol force to spatially distinct commands (precincts or divisions, etc.).
(3) Allocating to duty tour, watch, or shift.
(4) On each tour, assigning to patrol beats or sectors.
(5) Determining the number, size, and shape of sectors.
(6) Determining the number of tours per day and their starting time (these may vary spatially across a city).
(7) Evaluating various technological innovations and administrative policies such as explicit priority structures on incoming calls for service, overlapping patrol car sectors or beat plans, car locator systems, and real-time command, control, and communications systems.

Some of the criteria discussed below may be relevant to all these decisions but most are relevant to only a few.

The Operation of Patrol

Figure 1 is a simple block diagram of police patrol operations relevant to three major functions: (1) prevention and deterrence of crime, (2) apprehension of suspected criminals, and (3) response to calls for assistance.[2] The discussion of criteria in this chapter will be organized by these major functions of police patrol.

A distinction is made on the diagram between calls for assistance regarding noncrime matters and the response process set in motion once a crime has been detected by sources other than patrol (alarms, victims, witnesses, etc.). The response process is depicted in more detail because different criteria may apply and different police resources may be available in each step of the process.

Evaluation of Patrol Operation

Figure 2 displays, for each of three major patrol functions, a variety of criteria that may be relevant to the decisions and problems listed above. For each

[1] In this discussion we do not explore either the needed overall police force strength nor the proper fraction of the force that should comprise patrol, given an overall force level. We merely discuss criteria that bear on the needed patrol force strength without reference to other police department needs.

[2] Resources and factors exogenous to police patrol are omitted from this formulation. That is, police patrol may be thought of as only one element in a larger system that affects crime prevention, apprehension of suspects, and response to calls for assistance from the public. For example, detectives and the public's cooperation play important roles in apprehension of suspects; the fire department and, in some cities, a municipal ambulance service respond to certain calls for assistance; and many exogenous agencies and factors are thought to influence crime prevention and deterrence such as sentencing practices of judges, the correctional process, and basic demographic and socioeconomic factors (income, education, sex, age, private expenditures on security measures, and so on).

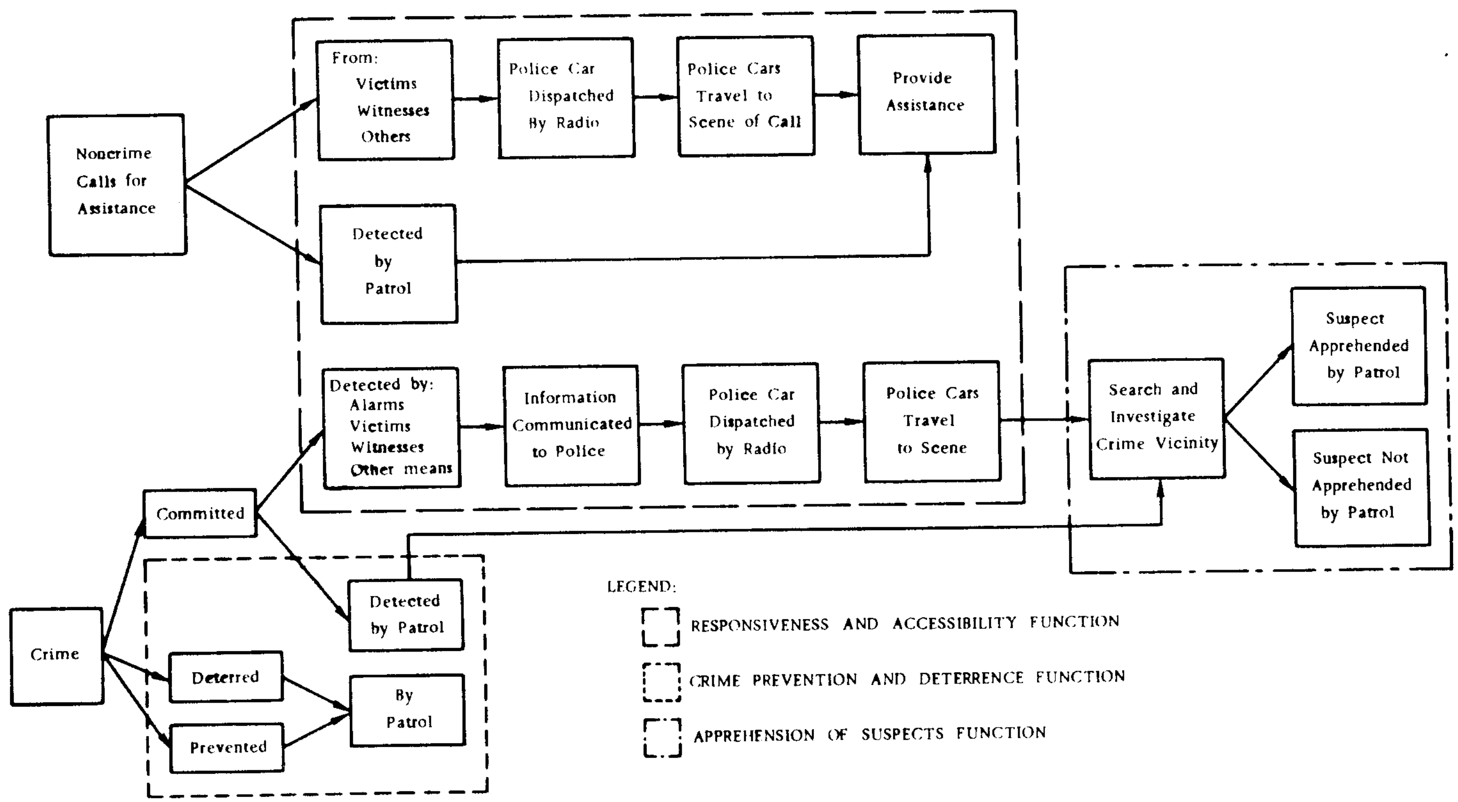

Fig. 1—Selected police patrol operations

RESPONSIVENESS AND ACCESSIBILITY	CRIME PREVENTION AND DETERRENCE	APPREHENSION OF SUSPECTS
A. Input and Proxy Criteria 1. Number of patrolmen and patrol cars on the street.* 2. Calls for assistance and crime per patrolman or patrol car on streets.* 3. Patrolmen or patrol cars* per square mile or per street mile. 4. Patrolmen or patrol cars* per population. 5. Travel distance to the scene. 6. Percent of time patrol car is utilized. 7. Percent of dispatches that are intersector. 8. Delay and fraction of calls that incur delay in dispatcher queue due to patrol force saturation or congestion.* *Disaggregated spatially and temporally.	A. Input and Proxy Criteria 1. Patrol man-hours or car-hours.* 2. Patrol man- or car-hours per square mile or street mile. 3. Patrolmen or cars* per population. 4. Hours of preventive patrol per population. 5. Patrol frequency. 6. Hours of preventive patrol per "suppressible" crime. 7. Arrest rate by patrol and charging rate resulting from patrol arrests. 8. Crime intercept probability as perceived by criminals. 9. Percent of patrol man-hours spent on the street. *On the street.	A. Input and Proxy Criteria 1. Patrol man-hours and patrol car-hours on the street. 2. Patrolmen or patrol cars* per square mile or per street mile. 3. Patrolman or patrol cars* per population. 4. Hours of patrol per population. 5. Patrol frequency. 6. Hours of preventive patrol per "suppressible" crime. 7. Crime intercept probability. *On the street.
B. Output Criteria or Measures of Effect 1. Elapsed time from communication to police of need for service until arrival of that service.* 2. Elapsed time from communication to police of need for service until provision of service is completed.* 3. Accessibility of communications mechanisms, given an event has been detected but not yet reported, as measured by time delay. 4. Percent of callers satisfied with service. *By type of call-for-service.	B. Output Criteria or Measures of Effect 1. Number of crimes* (reported, true, prevented). 2. Percentage change in number of crimes* (reported, true). 3. Victimization rate* (reported, true). 4. Social and economic costs of crime (loss of life, property, sense of security, etc.) *Categorized by type of crime and victim.	B. Output Criteria or Measures of Effect 1. Number of arrests by patrol. 2. Rate of arrests by patrolmen.* 3. Charging rate resulting from patrol arrests.* 4. Conviction rate resulting from patrol arrests.* *By category of crime with an indication of whether arrest was made while on preventive patrol or while responding to a call.

†The manner in which these criteria are used will affect whether they measure effectiveness or equity. For example, citywide average response time might be used to judge patrol response effectiveness, while the variation of response time between neighborhoods might be used to judge the equity of patrol response.

Fig. 2—Some criteria for police patrol programs

function, the criteria are grouped under two categories: input and proxy criteria; and output criteria or measures of effect. That is, some criteria in use are clearly measures of police input or activity. Some are indirect or proxy measures of effect or output. Finally, some are truly measures of output or effect.[3] Our discussion of criteria follows the structure depicted in Fig. 2.

For each criterion or set of criteria we will discuss, where appropriate, its relevance to the decisions mentioned above and how it might be incorporated into models of patrol operations. Wherever possible, each criterion is appraised in terms of properties such as measurability, variability, sensitivity to patrol policy changes, and its potential audience's understanding and acceptance.

Measurability has several facets: the ease or difficulty in determining values of a criterion; dollar and manpower costs of obtaining and processing the information; and the frequency with which reliable measurements of the criterion value may be taken. The variability of the measured value of a criterion affects its usefulness in monitoring the effects of patrol policy changes. For example, the homicide rate in a very small jurisdiction could vary several hundred percent from year to year as a result of random events not controllable by the patrol force.

Criteria may be measures of efficiency, effectiveness, or equity. Generally speaking, *efficiency* deals with measures that are *internal* to the system. Input and proxy criteria usually measure efficiency. For example, in waging a newspaper advertising campaign, a measure of efficiency might be the cost per reader reached. For police patrol, a measure of efficiency might be the average fraction of a given patrol force that is on the streets over a specified time period. *Effectiveness,* on the other hand, implies measuring output or *external* effects. For example, a measure of effectiveness of an advertising campaign might be the cost per additional item sold. For police patrol, measures of effectiveness might be the change in reported crime volume (or crime rate), average response time to calls for assistance, and the fraction of calls for assistance answered immediately. Equity has to do with how a service and its benefits are distributed among the population.

How a criterion is understood, valued, and perceived can vary markedly, depending on the audience. Agency administrators are generally concerned with the efficiency and effectiveness of overall programs and policies and, thus, criteria should reflect such concerns. The general public is likely to value and accept criteria or indicators that are readily understandable and relevant to everyday life. The public is very concerned with how a service is *distributed* among various groups. That is, a group, whether defined by a common neighborhood, a common economic endeavor (such as small shopkeepers), or whatever, is interested in "*equity*"— in obtaining their "fair share" of that service. How "equity" ought to be defined is a knotty and delicate issue. A citizen's desire for an equitable distribution of the

[3] Realizing that it is often difficult to make distinctions between input, proxy, and output criteria (especially since the outputs or measures of effect may not be widely accepted), any list of criteria is, to some extent, arbitrary. Moreover, certain criteria cannot be neatly catalogued by police function. In our judgment, Fig. 2 represents one reasonable categorization of criteria.

benefits of a municipal service such as police patrol might imply alternatively:[4]

- That each person should have equal *right* to benefits.
- That benefits should be uniformly *available*.
- That benefits should be available in proportion to *needs*.
- That benefits should be available in proportion to *economic* and/or *political contributions* of citizens to government.

Not only is equity difficult to define, but consideration of equity often implies increased data requirements, since values of the criteria must be displayed in a highly disaggregated way—by neighborhood and/or by time of day. Effectiveness considerations might, in some cases, only require display of average citywide values of a criterion. Wherever appropriate, we shall attempt to make distinctions and comparisons between efficiency, effectiveness, and equity.

A discussion of criteria for the patrol responsiveness, crime prevention, and criminal apprehension functions, respectively, is contained in the next three sections. Several other criteria not readily categorized under the functional headings of Fig. 2 (including those relevant to the traffic safety function) are discussed in the succeeding section. Before presenting suggested criteria, we discuss why a set of criteria should be used in patrol allocation and deployment decisions.

CRITERIA OF POLICE PATROL RESPONSIVENESS AND ACCESSIBILITY

Input or Proxy Criteria

In allocating patrol spatially and temporally, most police departments today use input criteria as proxies for measuring patrol responsiveness and accessibility. These range from very crude, pure input measures such as *number of patrolmen and/or patrol cars on the street per population, per square mile,* or *per street mile* to measures which take into account demand for service, and thus are better proxies for measures of effect. These proxy criteria include *calls for assistance per patrolman or per patrol car on the streets.* Sometimes, serious calls (crime and noncrime) receive more weight or emphasis than do less serious calls.

The increase in overall police manning level or budget and the increase in the number of patrolmen and patrol cars on the streets are examples of input criteria used as proxies for measures of increased effectiveness. In their political rhetoric regarding efforts to combat crime and preserve public order, high city officials, as well as police officials, employ such criteria in defending budgets for citywide patrol force strength.

[4] A forthcoming Rand report by M. H. Krieger deals with social reporting for a city. It includes a discussion of service indicators and the concerns of the several audiences about such indicators. Some of the above discussion has been influenced by Krieger's notions.

None of these criteria, singly or in combination, measures police responsiveness and accessibility in terms directly related to patrol operation and its effects. However, these criteria have traditionally been employed because they are easily understood and measurable, and the necessary data are routinely collected for other purposes.

We will argue below that a readily measurable criterion of overall police responsiveness and accessibility is the patrol *response time,* i.e., the time from receipt of a call for police services until the arrival of a patrolman at the scene. Several of the criteria displayed in Fig. 2 are proxies for response time, and are less desirable, since they are less direct measures of patrol responsiveness. These proxies for response time include the *maximum travel distance within a sector,* the *fraction of calls that incur delay in the dispatching queue* due to patrol car unavailability, the *fraction of the time which a patrol car is busy,* and the *fraction of dispatches which are intersector.* [5]

Output Criteria of Patrol Responsiveness and Accessibility

One set of criteria that is related directly to patrol operations and that attempts to measure police responsiveness and accessibility includes:

- Response time—elapsed time from arrival of calls for assistance to arrival of police service.
- Accessibility of a communications mechanism, or system, given that a need for service is detected but not yet reported. An appropriate criterion might be the elapsed time from realization of need for service until communication of that need.

Response time to calls for assistance, once an attempt is made to notify police via telephone or alarm system, has several components, namely, time from attempted communication until successful contact with police (T_1), telephone conversation time (T_2), information recording time (T_3), dispatcher queue delay (T_4), dispatcher service time (T_5), and travel time (T_6). We denote the service time at the scene as (T_7). Which portion of response time is policy relevant depends on the patrol decision and operation under consideration. For determining the number and scheduling of complaint clerks (telephone operators) in the communications center, T_1 and T_2 are relevant. In designing and evaluating alternative police communications and dispatching systems or real-time command-control systems, T_1, T_2, T_3, and T_5 are relevant. For determining overall patrol force strength and allocation of patrol spatially and temporally (given a specified communications and dispatching system), T_4, T_6, and T_7 are relevant.

The discussion of response time will assume that reduced response time means more effective police service. Little hard evidence exists that rapid response

[5] That is, those calls that are answered by patrol cars from nearby sectors or beats, rather than the patrol cars assigned to the beats in which the calls originate.

is important in raising the arrest probability near the scene of a crime, although a study conducted for the Crime Commission points in that direction.[6] Some police officials also claim that quick response solves more crimes.[7] Reduced response time to fires and accidents may save lives, reduce suffering, and prevent some economic loss. Reduced response time to calls for assistance involving family or other disturbances, may prevent some from escalating to serious crimes. But the value of response time in the provision of police services is not known, nor are we likely to understand it without long, costly, and careful analysis and experimentation.

Response times might be classified by priority class of call. A minimal set of priorities might comprise four types of calls:

- *Urgent*—preempt all other activity and respond as quickly as possible (for example, robbery in progress, officer in trouble).
- *Important*—respond with all deliberate speed (disturbance, prowler).
- *As available*—respond only after first two categories of calls are serviced (report of a past auto theft).
- *Screen out*—no "on scene" police patrol assistance required[8] (information request).

It would, of course, be extremely useful to know the cumulative probability distribution of all components of response time as a function of policy parameters (such as number of allocated patrol units). In lieu of the distribution, a measure of the "tail" or skewness of the distribution might be utilized. For example, we could apply a criterion for allocating patrol units to regions or neighborhoods and by shift such as *no more than p percent of the responses incur a delay greater than t minutes.* It is sometimes satisfactory to use simpler averages or "central tendency" attributes such as an arithmetic mean, mode, or median. Because of the critical nature of time in police work, it is often desirable to use measures of distribution skewness as well as measures of central tendency.

Table 1 displays very rough bounding values and typical values of delays observed in monitoring police operations in Boston and New York City.[9]

Table 2 displays several response-time components by type of call. These data are drawn from observations in the Boston Police Department during 6-12 June 1966.

[6] *Task Force Report: Science and Technology*, The President's Commission on Law Enforcement and Administration of Justice (prepared by The Institute for Defense Analyses), U.S. Government Printing Office, 1967, Appendix B.

[7] *Software Age*, December 1969, quotes the Chief of Police in Kansas City to the effect that "metropolitan police solve two-thirds of the crimes which they can respond to within two minutes. The same studies have shown that less than 20 percent of the crimes were solved for which the response was delayed more than five minutes."

[8] In addition to the normal call categories which truly do not require patrol assistance (such as information requests), there may be deliberate policy decisions which screen out certain call categories which are normally of low priority.

[9] These data are drawn from both a study in Boston by R. C. Larson, *Operational Study of the Police Response System*, Technical Report No. 26, Operations Research Center, Massachusetts Institute of Technology, 1967, and studies of the New York City Police Department by The Rand Corporation (unpublished).

Table 1

OBSERVED VALUES OF POLICE PATROL RESPONSE TIME (BY COMPONENT)

(Minutes)

Response Time Component	Typical Lower Bound	Typical Upper Bound	Typical Value*
T_1--Time from attempted communication until successful contact with police	0	1	0.05
T_2--Telephone conversation time	0.2	5	1
T_3--Information recording time	0.2	0.6	0.4
T_4--Dispatcher queue delay	0	60	0.5
T_5--Dispatcher service time	0.1	1	0.2
T_6--Travel time	0.5	10	5
T_7--Service time	5	120	30

Table 2

RESPONSE-TIME COMPONENTS BY INCIDENT TYPE

(Minutes)

	Queueing Delay + Service Time at Dispatcher ($T_4 + T_5$)		Travel Time (T_6)		Service Time (T_7)		
Incident Type	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	Sample Size
Vehicular accident	1.05	1.00	3.98	3.09	54.25	25.97	44
Medical case	1.73	3.01	5.35	3.38	40.38	24.74	225
Drunk	2.31	3.83	5.34	4.26	25.31	25.89	71
Burglary	2.39	4.24	6.45	5.05	51.76	31.36	33
Investigation	2.61	5.23	5.94	4.53	31.30	23.56	509
Minor disturbance	3.46	6.11	5.95	3.64	24.39	18.56	406
Auto theft	4.83	8.08	7.09	4.35	35.54	21.87	94

These data exhibit a number of properties:

(1) There exists an implicit priority structure, as evidenced by successively increasing mean values of dispatcher queueing plus service time ($T_4 + T_5$), and by the fact that the rank ordering of travel time (T_6) is almost identical to that for ($T_4 + T_5$).
(2) Service time (T_7) is unrelated to priority.
(3) The standard deviations of delays at the dispatcher ($T_4 + T_5$) are typically twice the mean values, indicating a distribution with a long tail.[10]
(4) The standard deviations of travel times (T_6) are typically between one-half of the mean and the mean value itself. Existing simple models of response time suggest that the standard deviation of response distance should be about one-half of the mean response distance. Additional variations in response time may be due to speed fluctuation and nonoptimal dispatcher decisions.

It is interesting to note that various formulations of response time are used as proxy criteria in studying other emergency services such as fire and ambulance. A recent report on criteria selection in emergency medical services indicates that elapsed time to care and treatment is a good proxy for the "ultimate" measures of effect, which include medical outcome and reduction of suffering.[11] These ultimate measures of effect also cannot now be estimated. Rand's studies for the New York City Fire Department indicate that various formulations of response time are reasonable proxies for the "ultimate" measure of effect; this ultimate measure is conceived as a multidimensional "cost of fire" which includes fire damage, loss of life, and injury to civilians and firemen. In particular, excess wait beyond a certain time for fires which are serious (rather than for all fire alarms) is one suggested criterion. An analogous criterion would be equally applicable to emergency ambulance service in serious cases or accidents.

Returning to the criterion of police patrol response time, we observe that it possesses the useful properties of measurability and policy sensitivity. Furthermore, it is also understandable and meaningful to consumers of police service, the public. The citywide mean value of response time, over some specified time period, is a good measure of *effectiveness* of overall police responsiveness and accessibility. However, the citywide average value of response time (from receipt of the call until patrol car arrival at the scene) coupled with the percentage of the responses involving times which exceed an acceptable time limit t[12] is a better combined measure of effectiveness of police responsiveness and accessibility.

How response time varies among neighborhoods, groups of people, and time of day is a useful measure of *equity*. One specific and useful formulation of equity

[10] The aggregated distribution is displayed in R. C. Larson, op. cit., Appendix.

[11] See R. B. Andrews, *Criteria Selection in Emergency Medical System Analysis*, EMS-69-1-W, Emergency Medical Systems Project, Graduate School of Business Administration, University of California, Los Angeles, June 1969.

[12] Dependent on the priority of the call.

in response time might be to allocate patrol units in such a way that (1) no citizen need wait more than t minutes on the average anywhere or anytime in the city for a patrol car, and (2) less than p percent of the calls from any neighborhood during any time period will not receive a patrol car response within t minutes.[13] The value of using multiple criteria for allocating patrol units is discussed more fully below. These multiple criteria are also relevant in measuring the responsiveness of other emergency municipal services such as fire protection and emergency ambulance service. It should not be assumed that the proportion of each type of call is independent of neighborhood and that police and citizens view the seriousness or urgency of a specified type of call uniformly throughout the city. The first assumption would generally not be true because, for example, family disturbance calls might account for a much larger proportion of the total calls in one neighborhood compared to another. Therefore, the response-time criteria of effectiveness and equity should be considered by type, or priority class, of call. The second assumption may also be invalid if, for example, the police's or the public's views of the seriousness of a particular incident and their service expectations differ in different neighborhoods. Is a family disturbance call from a slum area viewed with a good deal less seriousness and importance by either the police, participants, or observers than if it comes from a wealthy district in the city? Thus, ideally, each type of call should be weighted by its measure of importance in each neighborhood. In fact, observation suggests that actual police response time to similar types of calls in different neighborhoods reflects such implicit weightings.

Accessibility to means for citizens to communicate with police is important in overall response time. An appropriate criterion might be the *elapsed time from detection or realization of need for service until communication of that need.* Common mechanisms include telephones, patrol cars that are hailed by citizens in need, police call boxes (in some cities), etc. This delay is affected only marginally by patrol deployment strategy and police call box systems, since most calls for assistance arrive by telephone.

Ideally, we would like to measure police responsiveness and accessibility directly in terms of citizen satisfaction with that aspect of police service. However, satisfaction is very difficult to define and measure. Perhaps some form of citizen survey would be useful. Such a survey might also attempt to measure the quality of service after arrival at the scene.

CRITERIA OF CRIME PREVENTION AND DETERRENCE

A second set of criteria are grouped under the crime prevention and deterrence function of patrol. The preventive patrol activity and, to some extent, the ability to respond rapidly to calls for assistance are the two patrol activities most relevant to the prevention and deterrence function. By posing the risk of apprehen-

[13] Time and percentage are dependent on the priority of the call.

sion (and subsequent conviction and incarceration), preventive patrol is said to *deter* individuals from committing crime. By removal of certain crime "hazards" (e.g., open or unlocked doors and windows), preventive patrol is said to *prevent* crime. The extent (both qualitatively and quantitatively) to which this distinction is valid has not been determined. In fact, as we shall see below, the extent to which preventive patrol affects crime rate (a measure of the combined effects of prevention and deterrence) has not been quantified satisfactorily.

Input and Proxy Criteria of Crime Prevention and Deterrence

Police have traditionally used a variety of input and proxy criteria in allocating patrol for the crime prevention and deterrence function. Pure input criteria include the following: *number of patrolmen and/or patrol cars on the street; fraction of patrol force on the street; patrol man-hours or patrol car-hours per square mile or per street mile or per 1000 population; and patrol frequency* (i.e., the number of times a patrol unit passes a specified point per unit time). Proxy criteria would take into account demand level, that is, crime volume or rate.[14] These might include the following: *number of patrolmen and/or patrol cars, or patrol frequency per 1000 crimes or per crime rate* (crimes per population or victimization rate); and *patrol hours per 1000 crimes or per crime rate.* The proxy criteria are more meaningful if weighted by importance, seriousness of crime, or susceptibility to suppression by preventive patrol. A good deal of work has been done in attempting to scale or measure seriousness of crime.[15] Furthermore, it is reasonable to assume that preventive patrol is much more likely to prevent and/or deter "outside" crimes of property and violence rather than crimes which, by and large, occur in places where police patrol could not observe the event.

None of these criteria fully possess the four desirable properties mentioned earlier. Comparatively speaking, some are "better" than others, to the extent that factors which vary among patrol commands—such as population and crime density, traffic conditions, topography, geography, and natural barriers (rivers, bridges, railroad tracks)—affect the appropriateness of a criterion. Of the input criteria listed above, *patrol frequency is perhaps the best.* Existing models can predict patrol frequency with fair accuracy and the measure itself can account for the effects of street miles, traffic conditions, and topographical factors. Patrol frequency is understood by the public, but in practice it is not very controllable, because of varying call-for-service workloads and the current inability of police administrators to monitor

[14] There are a host of complexities which arise whenever crime rates are to be employed. It is not our intention to discuss those complexities here but rather to note that difficulties exist. One problem is that wide variations exist in the definition of crime. The FBI's "Uniform Crime Reporting" system has made great progress in standardizing the definitions of certain major crimes. Another difficulty in using crime rates (crimes per population) is the size of the population base to be used. One of the cities we studied has a daytime population which is twice the size of its resident population. There is also a large discrepancy between true crime and reported crime, as previously noted.

[15] See, for example, the classic study by Thorsten Sellin and Marvin E. Wolfgang, *The Measurement of Delinquency*, John Wiley and Sons, New York, 1964.

patrol car positions.[16] The common practice of concentrating cars in neighborhoods where call-for-service volume is high and having the cars perform preventive patrol when not answering calls may have adverse side effects. For example, almost no preventive patrolling is conducted when the volume of calls for service (and perhaps suppressible crime) is highest.[17] Also, suppressible crimes may not be geographically coincident with high call-for-service volume.

The proxy criteria listed suffer from similar inadequacies, but connecting patrol cars, patrol hours, or patrol frequency to suppressible crime or crime rate makes these criteria more meaningful and relevant, in our view. We assume that more crimes can be deterred at times and in areas where suppressible crimes occur.

The distribution of preventive patrol by neighborhood is a measure of equity. But there are various conceptions of equity. Should preventive patrol be allocated spatially and temporally so as to equalize the number of patrol cars per street mile, patrol cars per citizen, patrol frequency per citizen, patrol hours per outside crime, or patrol hours per victimization rate? Presumably, these alternative formulations attempt to make preventive patrol services uniformly available or available in proportion to "needs" or "benefits." Or, is it more equitable to allocate preventive patrol in proportion to a neighborhood's average income or tax contributions (i.e., their ability to pay)? In practice, actual spatial allocation of patrol units, as measured by criteria similar to those described, will probably fall between these conceptions of equity. That is, preventive patrol will neither be uniformly available, nor available strictly in proportion to "need," nor strictly in proportion to ability to pay. Judging from our limited survey of police departments, many collect very little information on where and when preventive patrolling is performed.

A rise in *arrest rate*[18] and *charging rate*[19] resulting from patrol arrests may deter criminals. Of perhaps the most relevance to crime deterrence is the criminal's perception of his chances of being apprehended, charged, convicted, and incarcerated in relation to the rewards expected from his criminal acts. However, actual values are much more easily measurable than perceived values. We suggest the use of charging rate as a way of measuring "valid" arrests. Arrest rate alone is susceptible to manipulation (either by management policy decisions or by the exercise of discretion in the field) by patrol forces. The conviction rate may be less useful than charging rate because of the substantial time lag between arrest and final disposition by the court.

[16] Police call-box systems installed in some cities allow monitoring of a foot-patrolman's position and progress through his beat. Patrol car positions cannot now be monitored accurately and frequently at an acceptable cost. Automatic car location systems, currently in development, seem to have promise for the future.

[17] By suppressible crimes, we mean those types of crimes that may be significantly deterred or prevented by police patrol activity. While the actual types of crimes which are affected by patrol are not well understood, one possible categorization, used in New York City, is all "outside" crimes, i.e., those that either occur on the street or which could be detected by a patrolman from the street. These include, for example, most street muggings but relatively few burglaries.

[18] Number of crimes resulting in at least one arrest divided by the number of reported crimes for the crime categories of interest.

[19] Number of crimes for which one or more suspects are formally charged in the judiciary branch of the criminal justice apparatus, divided by the number of reported crimes.

Crime intercept probability, both real and as perceived by criminals, is an important measure that should be closely related to arrest rate. Present models predicting actual crime intercept probability are rather simple, assuming independence between the positions of crime and patrol cars. The use of these models has underscored the questioning of the value of preventive patrol, for the crime intercept probabilities predicted by these models are small and probably upper-bound estimates to the true probabilities. For reasonable parameter values, the computed probabilities are remarkably small (often less than 0.01). So, unless perceived probability is markedly greater than the actual probability, preventive patrol may have little chance of being effective in a crime deterrent role. But such models of crime intercept probability do not address certain aspects of the prevention role of patrol such as removal of crime opportunities through window and door checks.

Output Criteria of Crime Prevention and Deterrence

A set of criteria that measure more directly the output or effects of preventive patrol would include the following:

- Number of crimes (reported, true, prevented).
- Percentage change in number of crimes (reported, true).
- Victimization rate or its rate of change.
- Public attitudes and cooperation.
- Social and economic costs of crime.

The number of crimes, the change in number of crimes, and victimization rate (categorized by victim and crime type) are clearly relevant but are partial measures of effectiveness.[20] Historical data, of course, provide statistics only on *reported* crime. One problem is that no theoretical basis now exists for relating different levels or strategies of preventive patrol to reported crime or victimization rate. Nor is hard, quantitative evidence available from careful experimentation. Another problem, now well known, is that much crime goes unreported, and, for a variety of reasons, some crime types are underreported more than others.[21] One cause of underreporting is the victim himself (e.g., in crimes of rape, or shoplifting). The other cause is the police's internal crime reporting system and its built-in incentives or disincentives to produce accurate statistics from those reported to it by the public. In one large city, for example, a change in the incentives and system for reporting crime led to a sudden annual rise of 70 percent in crimes reported by the police. It was estimated that 63 percentage points of the increase was due to the

[20] Analogous criteria for fire protection and emergency ambulance services are number of fires, by type or seriousness (reported and true number); fire victimization rate; number of requests for emergency ambulance service; and the changes in these quantities over time.

[21] See, for example, A. Biderman, et al., *Report on a Pilot Study in the District of Columbia on Victimization and Attitudes Toward Law Enforcement*, Field Surveys I, Bureau of Social Science Research, 1967, and P. H. Ennis, *Criminal Victimization in the United States: A Report of a National Survey*, Field Surveys II, The National Opinion Research Center, May 1967; both studies conducted for the President's Commission on Law Enforcement and Administration of Justice.

change in the *reporting* system and the *real* increase in crimes reported by victims to the police comprised only 7 percent.

Although the marginal effect on reported crime of different patrol force levels is not known, there are indications of what may happen if patrol force level is suddenly reduced drastically. The police strike in Montreal on 7 October 1969 is a case in point at one end of the force level spectrum.[22] The normal police force of some 3780 men and 686 vehicles struck early in the morning. Only some 47 men (all ineligible for membership in the union) remained on duty relaying distress calls to the Quebec Provincial Police (QPP). By 10 a.m., 200 QPP were mustered and 40 patrol cars were on the streets. By early evening, 500 QPP were mustered, with 300 more on the way. But, being unfamiliar with Montreal, the QPP were quite ineffective. What happened? During that day, the reported crime volume was twelve times normal, bank holdups for that 24-hour period alone totaled 10 percent of the yearly volume, 49 persons were wounded or injured, and losses and damage exceeded $1 million. But, according to the author, it was not only the rise in professional crime that counted.

> It was the way political grievances, and private group frustrations, shot to the surface when no one was around to enforce the law. These included: an attack by taxi drivers on a company holding an exclusive franchise to provide limousine service at Montreal's International Airport; an attack by French-Canadian separatists on symbols of the English Establishment; an attack on the Mayor's property by social agitators who contend that not enough is being done for the poor; an attack on the United States Consulate by anti-Americans and, then simply, an attack on a code of ethics and behavior by conventional men and women who chose to join a mob.[22]

No data exist, of course, at the other end of the force level spectrum. But a reasonable hypothesis is that much, or even most, outside, suppressible crime would probably be deterred and prevented if there were patrol units on every corner.

True crime, change in true crime, true victimization rate, and *change in true victimization rate* would be better measures of the effect of preventive patrol. Like most measures, however, they may be affected by many things in addition to preventive patrol. The victimization survey, with all its methodological difficulties and its high cost, is still the best available method for estimating these parameters, at least for crimes against unwilling victims. Obtaining accurate estimates, using survey techniques, of true crime or true "victimization" rate for crimes with willing victims (e.g., gambling, use of narcotics) is probably hopeless, unless one simply assumes naively that respondents would answer truthfully. But use of such criteria as true crime in the predictive evaluation of police patrol policy must await the results of

[22] See Gerald Clark, "What Happens When the Police Strike," *New York Times Magazine,* 16 November 1969.

a careful series of experiments aimed at determining the relation between crime and patrol policy. However, once known for a variety of patrol parameters in a variety of cities, these relationships could be used in virtually all of the decision issues posed above.

Interesting equity-effectiveness questions may arise in using crime (or change in crime) as opposed to victimization rate (or change in it) as criteria for allocating patrol units. A simple hypothetical example illustrates how different allocations might result. Assume that a town has two districts, A and B, and the population, true number of annual crimes, and true victimization rate (or probability) in each district are as shown below.

	District	
	A	*B*
Population	1000	500
True annual crimes	100	100
Victimization probability (crimes per capita)	0.1	0.2

Let us further assume that we know the marginal utilities of patrol strength, so that each additional preventive patrol unit assigned to district A reduces annual crime by 15, whereas the comparable figure for B is only 10.[23] Now, how should *additional* patrol units be allocated? If the measure is one of effectiveness, that is, to *maximize the reduction in crime citywide,* then all additional patrol units should be allocated to district A. However, if the criterion is one of equity, e.g., to allocate additional patrol units so that *victimization rate is equalized,* the first 5 additional cars should be added to district B (until crime = 50 and victimization rate = 0.1) and thereafter for every 2 cars added to district A, 3 should be added to district B.

The *social and economic costs of crime* are the "ultimate" criteria. Conceptually, at least, these measures take "everything" into account including direct dollar losses (or transfers) due to crime, indirect economic costs such as victims' medical costs and lost earnings, private spending on security measures, and social costs such as fear, with its concomitant social and economic consequences (activities foregone, loss in business income and service when stores close early in neighborhoods with a high crime rate, migration from central city to suburbs, and so on). More importantly, there is loss of life, suffering, and damage which cannot be measured adequately in dollars and cents. Clearly, if we do not now know the relationships between alternative patrol programs and true crime, we cannot now know how the social and economic costs of crime vary with police patrol programs.

Basic difficulties exist in estimating the social and economic costs of crime. The President's Crime Commission attempted to estimate roughly, on a national

[23] We assume that the marginal utilities of patrol strength are constant (i.e., independent of the level of true annual crime) for illustrative purposes only. Actual marginal utilities, although unknown, are probably highly dependent on the level of crime.

scale, the economic impact of crimes and related expenditures.[24] However, numerous crime categories were omitted because of lack of statistics and, in some other cases, the estimates were of doubtful validity. Nevertheless, it was a first step. Substantial research resources would be required over a considerable period of time to construct a detailed framework for estimating social and economic costs and to begin to gather data on costs and attitudes. Some of the difficulties may never yield to research (such as the problems of incommensurates and unavailability of certain kinds of data), but, as the Crime Commission indicated, study is needed. Conceptually, at least, the social and economic costs of crime are the best measures for evaluating the relative effectiveness of the various crime prevention and control measures adopted by governments, businesses, and individuals—of which police patrol is but one.

As indicated in our earlier discussion of responsiveness and accessibility, similar difficulties and considerations apply to the "ultimate" measures of social and economic costs of fire protection and emergency medical service.

Until the difficulties in measuring true crime, true victimization, and the social and economic costs of crime are resolved, proxy measures must be utilized. To evaluate patrol crime prevention and deterrence activity, a combination of the following criteria might be employed: *patrol frequency, hours of preventive patrol per suppressible crime, arrest rate by patrol and charging rate resulting from patrol arrests, number and change in reported crimes, and reported victimization rate.* As discussed earlier, other measures such as preventive patrol man-hours or car-hours are more input oriented and of less value as proxies for measures of effect.

CRITERIA OF CRIMINAL APPREHENSION

A third set of criteria can be grouped under the function of apprehension of suspects by patrolmen.

Input and Proxy Criteria

The input and proxy criteria listed in Fig. 2, which might be used for evaluating patrol apprehension programs, have all been discussed in earlier sections. Criteria such as patrol man-hours or car-hours on the street and patrol frequency are much less relevant to apprehension than to the prevention function of patrol. Crime intercept probability, as estimated by analytic models, is a proxy for the actual number of arrests which could be used to estimate the impact of patrol program changes. However, the development and testing of such analytic models is only in

[24] By the following broad categories: crime against person, crime against property, other crimes (tax fraud, abortion, etc.), illegal goods and services (narcotics, gambling, loan sharking, etc.), public law enforcement and criminal justice, and private costs related to crime (prevention services and equipment, insurance, private counsel, bail, etc.). See *The Challenge of Crime in a Free Society*, a report by the President's Commission on Law Enforcement and Administration of Justice, U.S. Government Printing Office, Washington, D.C., February 1967.

the embryonic stage at present.

Certain patrol activities such as field interrogations, crime scene searches, and seizure of evidence may or may not lead to arrests. The evaluation of each of these vital and time-consuming activities would require special criteria which have more detail than we wish to discuss here. For the evaluation of the overall patrol apprehension program, we feel that the output criteria mentioned below are easily measurable, and thus should be preferred above criteria which only measure resource inputs to the apprehension program.

Output Criteria or Measures of Effect

Some criteria that measure this function of patrol more directly would include:

- Number of arrests by patrol.
- Arrest rate by patrol.
- Charging and conviction rates resulting from patrol arrests.

Number of arrests and arrest rate (attributed to patrol), and the change in these quantities, are direct measures of effect. We define arrest rate as the proportion of crimes (of a given type) which result in at least one arrest. Again, careful experimentation and analysis is required to relate alternative patrol programs to these measures before such criteria may be used with confidence in evaluating proposed patrol program changes. One existing problem is that number of arrests and arrest rate can be very sensitive to police administrative policies, [25] at least for certain categories of crime. Changing public pressure for enforcement or a change in top personnel in the police department or in city hall often leads to changes in law-enforcement policies. Given limited resources, police cannot enforce all laws uniformly. Over time, the resources and vigor devoted to enforcement of particular laws, say, gambling or prostitution, may vary considerably. This means that arrests and arrest rates for those crimes would vary too. Thus, care must be exercised when using historical arrest data in attempting to relate patrol programs to apprehension success.

The *number of persons charged,* by crime category, is a measure of the number of arrests which have been sanctified by the judicial branch of the criminal justice system. The *number of convictions,* or *conviction rate,* would be a better measure if the data are available in timely fashion. If there are long time lags between arrest and conviction (or other disposition) the usefulness of such criteria would be seriously diminished. Of the three measures of effect discussed, we feel that arrests and arrest rates are most sensitive to administrative policy and thus least useful in judging the apprehension effectiveness of patrol. On balance, then, charging rate appears to be the most useful measure of effect.

[25] The number of "clearances," that is, the number of crimes which detectives feel have been "solved," are frequently used for evaluation of detectives and are also very sensitive to administrative policy.

OTHER CRITERIA

There are other criteria, not neatly categorized under the three patrol functions discussed, that are, or might be, used for evaluative purposes.

Equal Workload

It is interesting to note that a widely accepted criterion in allocating and deploying patrol resources is to equalize patrol workload.[26] How equalization is defined varies with the allocation method used and with judgments about the relative importance of one factor versus another. Differences in workload have been used by police unions to claim job assignment inequities. Undoubtedly, the inability to relate patrol inputs to effects partially accounts for the widespread use of this criterion. Workload is certainly related to patrol service benefits. But the relationships can be very much dependent on how workload is defined. If each patrol unit services the same annual number of calls for assistance or crimes, there may be great variation in service time among units either because the same type of incident takes longer to service in one neighborhood compared to another, and/or because the proportion of incidents by type varies significantly among neighborhoods. Thus, there are better and poorer definitions of workload. It is our view that workload equalization should be viewed as an auxiliary objective, especially when better measures of effect are available. If a segment of the patrol force is "overloaded" with work, this should appear in more fundamental measures and can then be corrected.

Equalization of workload is also a widely accepted criterion in the provision of other municipal emergency services, such as fire protection and ambulance service, and the comments above apply with equal validity.

Police Injuries

For some patrol decisions the number of police injuries is used as a major criterion. The one-man versus two-man patrol car is a case in point.[27] For alternative policies which appear equally effective on other criteria, police injury potential should sway the decision. Since alternative policies are generally *not* equally effective, the decisionmaker must balance police injury potential against cost, effectiveness, and public risk.

Quality of Service

Earlier we stated that quality of service deals with the "adequacy" of services

[26] See, for example, O. W. Wilson, *Police Administration,* McGraw-Hill, Second Edition, 1963. Wilson is probably the most influential modern observer and practitioner in the field.

[27] From data we have examined, it would seem that injury rates for one-man cars are no higher, at least in cities which have modified their dispatching strategies so that at least two units respond to all potentially serious calls. See, for example, S. G. Chapman, *Police Patrol Readings,* Charles C. Thomas, Springfield, Illinois, 1964, pp. 120-144.

provided, in terms of degree, timeliness, and appropriateness. For the crime prevention and apprehension functions, many of the criteria already discussed really measure quality of service. For the responsiveness and accessibility functions, we have only discussed one aspect of quality, namely, timeliness. Degree and appropriateness of service can be estimated roughly by selected interviews and observations. Since police patrol is involved in such a great variety of services, it is probably necessary to attempt to measure quality by type of service rendered (e.g., auto accident, sick person aided, family dispute, disturbance, lock-out). Various characteristics of service such as perceived competence of officers, courtesy, response time, and relevance of information provided could be categorized and perhaps quantified.

St. Louis currently employs nonpolice audit of a sample of incidents to which patrol cars are dispatched. The primary purpose of this audit is to ensure the accuracy of incident reporting. In addition to a detailed examination of records, the audit procedure includes actual field interviews. Such an audit procedure, or some variant of it, also could be used to estimate quality of services. It is our view that the police need a procedure that will provide feedback regarding the quality of services rendered. The quality of other municipal services such as fire protection and emergency ambulance service could be estimated by a similar procedure.

Public Attitude

Public attitudes and cooperation toward police patrol programs influence the effectiveness of police; therefore, measures such as crime reporting rate, arrest rate, and presumably true crime rate may be affected. These attitudes and perceptions can be estimated by survey techniques and by responses to well-publicized programs such as "Operation Crime Stop," conducted in Chicago recently. It is also interesting to note that large recorded improvements in public attitude have resulted from minor changes such as repainting all patrol cars brightly—a change that apparently affects perceived safety and, perhaps, even affects a criminal's perceived apprehension probability.

Traffic Criteria

Although this paper focuses on other major functions of patrol, it is appropriate to mention briefly some criteria relevant to traffic safety policies and programs, since in some police departments, this function is carried out by patrol. The International Association of Chiefs of Police (IACP) suggests that *street miles* and *traffic volume* are appropriate criteria in allocation decisions. *Number of accidents*, appropriately categorized (e.g., nonserious, serious with injury, serious with loss of life), *number of moving violations*, and *number of parking violations*—all appropriately disaggregated geographically and temporally—are also relevant demand criteria. For allocating foot-patrolmen to traffic duty, the *number of congested intersection-hours* is a relevant criterion. And if police personnel are used as school crossing guards, the number of school crossings are relevant.

To evaluate the effectiveness of traffic programs, the accident rate per traffic mile and moving violation rate per traffic mile appear to be preferable to simple accident or violation volume, since the rates both compensate for changing traffic volume and express the risk a citizen incurs for each mile driven. Accident rate is clearly superior to violation rate, since it is less variable with administrative order, patrolman attitude, and patrol workload. However, some police departments employ a measure that combines these criteria. These are generally in the form of an enforcement index. One such index is defined as the *ratio of the number of moving violation convictions to the number of fatal plus nonfatal personal injury accidents.* An enforcement index of 20 is viewed as the minimum effective value by the IACP, the National Safety Council, and the Northwestern University Traffic Institute.[28]

Costs

A criterion such as *patrol budget per call for service or per crime* is a measure of the inputs rather than effects of patrol. Since salaries change and capital expenses may fluctuate markedly from year to year, costs are less reliable proxy measures of patrol effect than are man-hours or car-hours on the street. However, when coupled with crime and call-for-service volume or rate, the overall budget is an index of what the public is willing to spend in relation to the existing "need" for police.

If the relationships between crime and inputs into the various branches of the criminal justice system were known, for example, costs would be an excellent common measure.

SETS OF CRITERIA FOR PATROL PROGRAM EVALUATION

From the preceding discussion, it should be clear that a multiplicity of criteria are essential in addressing and evaluating patrol policy and allocation decisions. No single criterion is sufficient because patrol performs several functions and because often no single criterion measures a function adequately. The appropriate set of criteria depends on several factors, namely, the decision issue under consideration, the method of allocation, the cost and practicability of obtaining the necessary data from which values of the criteria can be estimated, geographic and demographic peculiarities of the city, and political considerations which may affect the relative priorities among patrol functions and/or the conception of equity in the delivery of services. In general, for a given decision question, the multiple criteria employed should attempt to encompass and measure as many of the patrol functions as possible.

In employing sets of criteria, care must be taken to guarantee that at least minimally acceptable levels of patrol performance are maintained for *each* criterion. *Thus, it is not appropriate to consolidate a set of criteria into one grand measure by taking a weighted summation of the values of the individual criteria.* All too often

[28] Ibid., pp. 378-379.

this latter practice results in one or two criteria unintentionally dominating all others. In general, however, one cannot simply and arbitrarily set desired levels of patrol performance for each of several criteria and assume that a patrol program exists which will meet or surpass all such performance levels. Tradeoffs may have to be made on levels of performance achievable for conflicting criteria. In any event, the minimally acceptable levels of performance for each criterion must usually be subjectively determined by the decisionmaker. Despite the difficulties inherent in working with a set of criteria, we believe the effort would be well rewarded. The primary values in using a set rather than a single criterion are (1) several different aspects of the patrol program can be evaluated, and (2) the tradeoffs, which *must* be made either explicitly or implicitly in every decision procedure, can be made with some explicit knowledge of how much is being gained and yielded based on several criteria when a particular patrol program is implemented.

In Chapter IV we describe and compare criteria and allocation practices currently used in several cities and describe potential improvements in allocation methods. The improved methods proposed in Chapter IV for addressing the resource allocation issues posed can handle several criteria simultaneously and attempt to ensure that minimally acceptable levels of patrol performance are maintained for each criterion.

CONCLUDING REMARKS

We have discussed criteria for evaluating the effectiveness, equity, and efficiency of a police patrol program in performing the functions of crime prevention and deterrence, criminal apprehension, and responding to calls for service. An attempt has been made to evaluate those criteria on their measurability, variability, policy sensitivity, degree of acceptability to the police and the public, and the degree to which the criteria measure program output rather than input. It is emphasized that no single criterion appears to be sufficient and that the set of criteria employed will depend on the circumstances of the individual police department and patrol programs to be evaluated. Recognizing the difficulties of generalizing, we suggest that the following set of criteria may have wide applicability.

A Preferred Set of Criteria

1. Patrol arrest rate by crime category.
2. Charging rate per crime by crime category with an indication of whether the patrol arrest occurred in response to a call or during preventive patrol.
3. Reported victimization rate by crime category and citizen group.
4. Reported crime by crime category.
5. Percentage of citizens satisfied with various aspects of patrol service.
6. Elapsed time from a call for police service until arrival of a patrol car;

measured by both the average time and the percentage of response times exceeding a specified time t.

7. Preventive patrol frequency.
8. Hours of preventive patrol per suppressible crime.
9. Resources expended: total patrol budget, total patrol man-hours and total car-hours plus a breakdown of each total into percentage allocated to each patrol function (administration, reports, preventive patrol, answering crime calls, noncrime calls, court appearances, etc.).

Citywide values of the first eight criteria above could be used to judge effectiveness, and comparisons of data disaggregated by time, neighborhood, and population group could be used to judge equity in the provision of patrol services. The relationship between resources expended (criterion 9) and the effectiveness achieved would measure the efficiency of patrol operations.

An ideal set of criteria might reflect true crime, true victimization, total social and economic impacts of crime, number of crimes prevented and deterred, plus criminal and the public attitudes in relation to alternative police patrol programs. Unfortunately, none of these quantities can be readily and accurately measured at present.

III. POLICE PATROL PROGRAMS IN SEVERAL CITIES: OBSERVATIONS AND COMPARISONS

INTRODUCTION

In the previous chapter we focused on evaluation criteria that might be used in evaluating alternative police patrol programs. However, discussions of evaluation criteria and methods for allocating patrol resources are of only limited value without real data. In this chapter we use information from several cities to make observations and comparisons of current patrol programs relevant to two of the three major patrol issues, namely the patrol force strength, and the organization and operational policies of the patrol force.

Existing data on crime, call-for-service workload, patrol strength and allocation, patrol organization, and operational policies enabled us to make only limited intercity comparisons and observations that are relevant to the three patrol issues of interest. The FBI annually reports citywide crime rates, by crime type, for U.S. cities.[1] The Kansas City Police Department annually surveys municipal police departments in the 37 cities whose 1960 Census populations were between 300,000 and 1,000,000.[2] This survey contains general administrative data, including police department budgets, police strength, manning by rank, function, and shift, salary, fringe benefits, and some organizational data. To our knowledge, these are the only two existing data sources that are readily available.

To accomplish the objectives of this study, it was necessary to collect additional information in several cities. The data included: demands for police service by police district and tour of duty, as well as for the city as a whole; patrol manning and patrol cars by police district and tour of duty; trends over time of demands for police service and patrol manning; patrol organization and operational policies; the internal police planning organization; the use of computers in police departments; criteria and methods of allocating patrol resources employed by police departments, and so on.

Limited resources restricted data gathering to six cities. These cities were

[1] *Crime in the United States, Uniform Crime Reports for the United States*, Federal Bureau of Investigation, U.S. Department of Justice (published annually).

[2] *Annual Survey of Municipal Police Departments*, Kansas City Police Department, Kansas City, Mo. (published annually).

selected with the following criteria in mind: city and police department size should range from medium to large; the sample should include cities that have a variety of patrol allocation methods, criteria, and operational policies; the sample should also include several police departments using more advanced methods and techniques; the sample should include both older and densely populated as well as newer and more sparsely populated cities. The participating police departments selected were Los Angeles City, Los Angeles County, St. Louis, Phoenix, and two other departments which requested that they not be identified.

Detailed questionnaires were prepared and submitted. In addition, each department was visited at least once by the authors in order to discuss the meaning and intent of the questionnaire as well as to gather additional information where available. In presenting and discussing the data and responses for the two cities which desired to remain anonymous, we have attempted to preserve that anonymity by altering the data in a consistent way, or by presenting the original data in a form where recognition is difficult.

First, we present a cross-sectional overview of the six cities, with the primary focus on measures for which data are readily available. Second, we present an overview of how the six cities have fared over the past decade (1960-1969). Third, we make comparisons of patrol organization, operational policies, and other operational features among the six cities. These features include: patrol hierarchy; beat assignment and rotation; dispatching; priority policies in answering calls for service; delays and responsiveness to calls for service; allocation of a patrolman's time; internal planning organization; use of outside consultants; and the uses of data and computers. Throughout, we indicate that because police departments do not routinely collect the relevant data, only a few of the evaluation criteria suggested in Chapter II can be utilized in these comparisons.

Finally, we present the results of some illustrative statistical analyses aimed at a preliminary exploration of the issue of proper overall police manning level. In this illustrative analysis we use both the six-city data set and a subset of 30 cities from the Kansas City Police Department Survey. The basic hypothesis here is that such techniques are useful in estimating the influence of police on the crime rate, thus providing insight into what the police force level ought to be. The analysis attempts to account for possible effects due to other factors such as population, area, population density, and other demographic variables. The results of the analysis are summarized in this chapter; the detailed analysis is presented in the Appendix.

THE SIX CITIES—A CROSS-SECTIONAL OVERVIEW

In essence, the overview that follows focuses primarily on the issues of overall patrol force level and its effectiveness. In an extremely condensed form, Table 3 summarizes the main features of the six city police departments surveyed. All data are for 1969, or 1968 if later figures were unavailable. The data are categorized by demographic characteristics, demand for police services (crime, calls for service,

Table 3

CITYWIDE COMPARISONS
(1969 data)

Item Compared	City of Los Angeles (LA)	Los Angeles County (LACO)	St. Louis (SL)	Phoenix (P)	City "X"	City "Y"
Population (residential)	2,917,440	1,792,659	675,000	560,000	(*)	(*)
Area (square miles)	463.6	3202.3	61.7	247.7	(*)	(*)
Population density (pop./sq. mi.)	6280	560	10,930	2260	15,300	13,300
CRIME AND CALLS FOR SERVICE						
Part I crimes	216,756	51,295	94,342	42,886	(*)	(*)
Part I crimes/population (victimization rate)	.074	.029	.14	.076	.106	.065
Part I + II crimes	N/A	207,704	N/A	68,952	(*)	(*)
Part I + II crimes/population	N/A	.116	N/A	.123	.146	.163
Part I + II arrests	248,000	81,791	41,563	35,674	(*)	(*)
Part I + II arrests/population	.085	.046	.062	.064	.072	.055
Calls for service	2,274,772	847,680	390,625	279,100	N/A	(*)
Calls for service/population	.78	.47	.58	.50	N/A	.54
POLICE RESOURCES (INPUTS)						
Police budget ($ millions)	85.0	68.75	25.1	12.85	(*)	(*)
Budget/population ($ per capita)	29.10	38.35	37.20	22.90	38.80	44.60
Total police employees	8582	5775	2774	1100	(*)	(*)
Percentage of civilians	27.9	24.4	24.0	17.0	20.9	16.5
Total uniformed patrol strength	3127	1860	1597	900	(*)	(*)
Patrolmen on street/shift	325	218	152	82	178	214
Patrol cars on street/shift	181	143	98	62	72	124
Total number of patrol cars	713	431	463	208	(*)	(*)

MEASURES OF INPUT, DEMAND, OUTPUT, AND EFFECTIVENESS						
Total budget/patrol car on 3 shifts ($/patrol car)	180,000	153,000	85,200	69,000	135,000	74,000
Total budget/patrolmen on 3 shifts ($/patrolman)	87,200	100,500	55,000	52,000	54,500	42,900
Total budget/total uniformed strength ($/patrolman)	27,200	37,000	15,700	14,300	18,300	17,800
Total budget/police employee ($/employee)	9920	11,900	9050	11,670	12,750	8820
Total budget/calls for service ($/CFS)	37.40	81.10	64.20	45.70	N/A	82.70
Total budget/Part I crimes ($/crime)	392	1342	266	299	366	689
Total budget/Part I + II arrests ($/arrest)	343	840	603	357	536	802
Police employees/1000 population	2.94	3.22	4.1	1.97	3.04	5.05
Uniformed patrolmen/1000 population	1.07	1.04	2.36	1.61	2.12	2.5
Patrolmen on street/shift/1000 population	.111	.122	.225	.147	.238	.347
Patrol cars on street/shift/1000 population	.062	.08	.145	.111	.096	.201
Patrolmen on street/shift/sq. mi.	.70	.071	2.46	.33	3.64	4.60
Patrol cars on street/shift/sq. mi.	.39	.045	1.61	.25	1.47	2.67
Calls for service/shift/area (CFS/shift/sq. mi.)	4.48	2.42	5.78	1.03	N/A	6.53
Part I crimes/shift/area (crimes/shift/sq. mi.)	.43	.15	1.40	.16	N/A	.78
Calls for service/patrolman on street/shift	6.4	3.39	2.35	3.11	N/A	1.42
Calls for service/patrol car on street/shift	11.5	5.4	3.64	4.11	N/A	2.45
Part I crimes/patrolman on street/shift	.65	.21	.57	.48	.41	.17
Part I crimes/patrol car on street/shift	1.17	.33	.88	.63	1.01	.29
Calls for service/uniformed patrol strength	729	456	245	310	N/A	215
Part I crimes/uniformed patrol strength	69.5	27.6	59.0	47.6	49.9	25.8
Part I + II arrests/uniformed patrol strength	79.3	44.0	26.0	39.7	34.0	22.2

NOTES: (*) -- Deleted to obscure the identity of the city; N/A -- Not Available.

victimization rates), police inputs (total employees, uniformed patrol strength, men and cars on the street), and measures of workload or output. Note that for Cities "X" and "Y," which have requested anonymity, we have omitted all absolute values of demand and inputs. Only demand per capita or per police input, and police budget per demand, or per square mile have been included.

An obvious, but important, observation is that most characteristics vary significantly across cities. The four named cities vary in residential population from roughly 0.5 million to 3 million, and population density (population per square mile) varies from a low of 560 in Los Angeles County[3] to a high of about 15,000 in City "X."

Absolute input characteristics shown include total police budget and employees, percentage of the police force that are civilians, uniformed patrol strength, total number of patrol cars, fraction of one-man and two-man patrol cars, and the average number of patrolmen and patrol cars on the street per shift. From the data provided it was not possible to estimate accurately the fraction of the patrol force assigned to street duty.

Other relevant inputs include total police per capita, patrol per capita, patrolmen and patrol cars per shift per square mile, and various budgetary measures such as dollars per patrolman.

Absolute annual demand characteristics include Part I crime, Part I and II crime, and calls for service. Absolute output measures include annual Part I and II arrests and convictions (where available). Victimization rate (crimes per capita) and calls for service per capita are also included.

However, for purposes of comparison, the most interesting criteria for which data are available involve ratios of demand or output and units of police input such as calls for service, crime, or arrests per patrolman or patrol car on the street on an average shift, or dollars per call or arrest or crime. Given the data available through interviews and questionnaire responses, it is not possible to estimate even citywide values for most of the criteria recommended in Chapter II. Thus, it is not possible to compare police departments on the basis of preventive patrol frequency, hours of preventive patrol per suppressible crime, patrol arrest rate, charging rate, fraction of citizens satisfied with patrol service, or various relevant response time measures.

Noting the large variation in various input, demand, and output measures among the six cities, we explored possible relationships by plotting several variable pairs. Illustrative plots are shown in Figs. 3 and 4.

Figure 3 shows the variation of several factors in relation to annual calls for service per capita. Note that annual calls for service per capita varies by almost a factor of two, with Los Angeles County generating less than 0.5 and Los Angeles City almost 0.8. Population density varies widely between a low of less than 1000 per

[3] The area in the Los Angeles County Sheriff's jurisdiction includes all unincorporated areas plus the areas of all contract cities which purchase all or part of their police services from the Sheriff's Department. Thus, cities such as Los Angeles and Santa Monica are excluded from consideration. But the Sheriff's patrol area does involve large, thinly populated areas such as the Antelope Valley, which reduces average population density considerably.

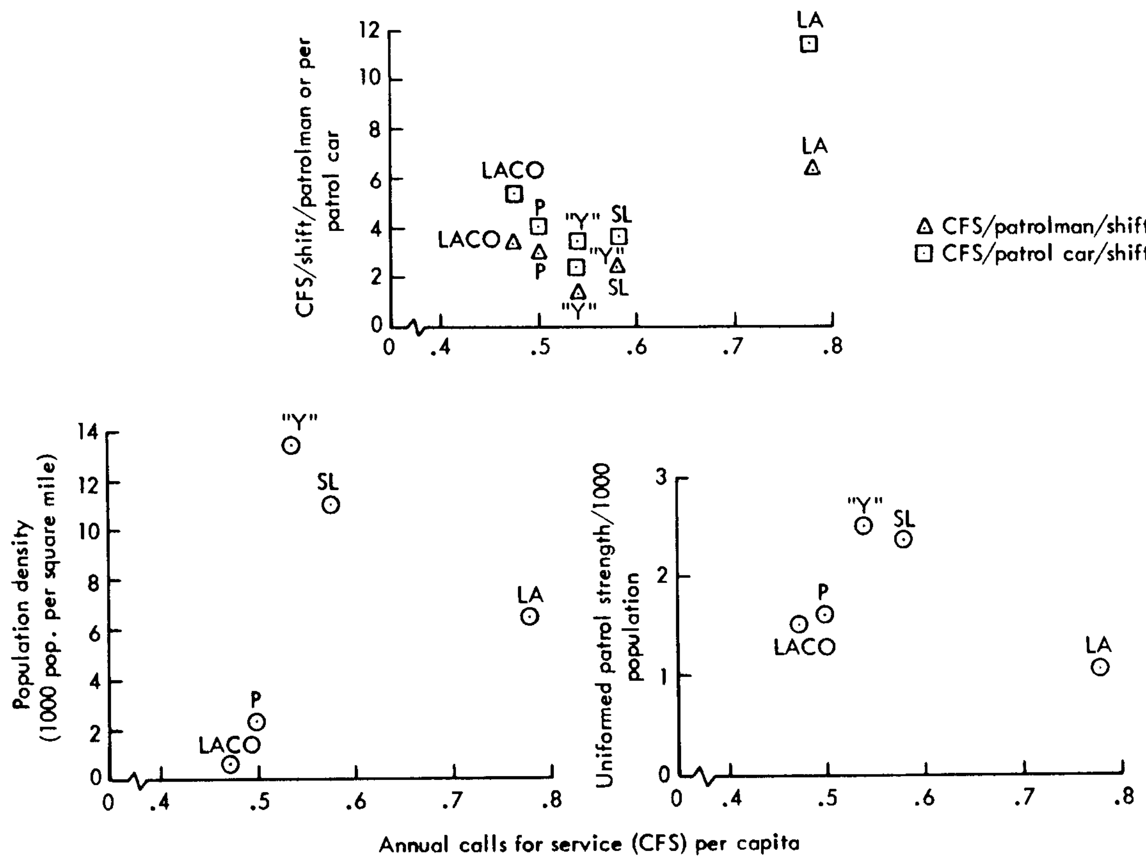

Fig. 3—Factors relating to calls for service per capita

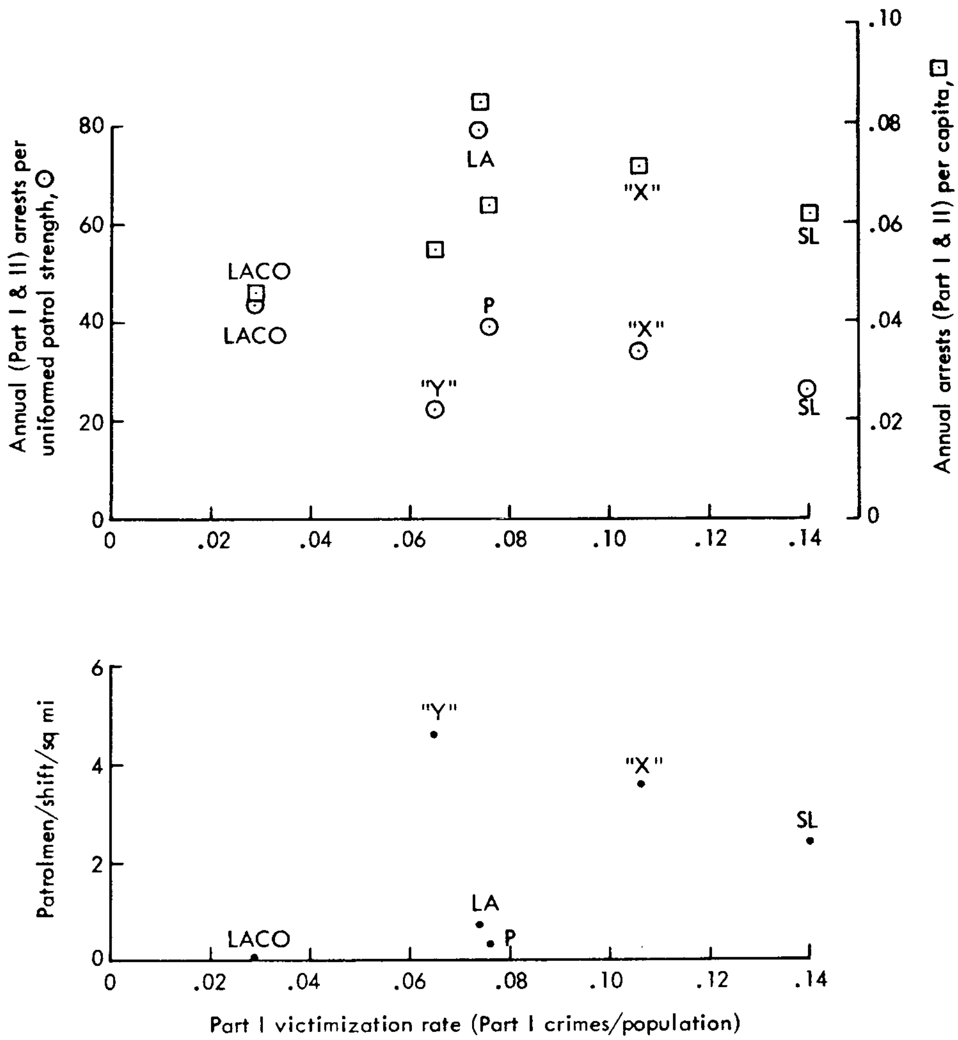

Fig. 4—Factors relating to victimization rate

square mile for Los Angeles County and a high of over 13,000 per square mile for City "Y." Although we indicate later that total calls for service and total patrol strength are positively related, they show no clear association on a per capita basis. Patrol strength per 1000 population also varies widely, from a minimum of about 1.0 for Los Angeles to a maximum of 2.5 for City "X." Call-for-service workload, measured on either a per patrolman per shift or per patrol car per shift basis, also shows large variation. City "Y's" workload is lowest—1.4 per patrolman and 2.5 per patrol car per shift. Los Angeles' workload is highest—6.4 per patrolman and 11.5

per patrol car. For a given city, the ratio of these two workload measures is the ratio of one-man and two-man cars in the field. Considering *all* patrol cars in the inventory, the cities' proportion of one-man and two-man cars are shown below (City "X" did not report specific figures):

Jurisdiction	*One-Man Cars (percent)*	*Two-Man Cars (percent)*
Los Angeles	15	85
City "Y"	31	69
Los Angeles County	46	54
St. Louis	66	34
Phoenix	83	17

Such comparisons for a small sample of cities provide little insight into the relationships between patrol strength or cars in the field and call-for-service demand. As we argue later in Chapter IV, more sophisticated techniques must be employed to evaluate the force level and allocation of police patrol (geographic and temporal).

Figure 4 explores the relationship between victimization rate and two factors: patrol density on the street per shift and annual arrests (Part I and II crimes) per capita. Patrolmen on the street per shift per square mile shows great variability. Note that residents of St. Louis have almost five times the chance of being victimized as do residents of Los Angeles County.[4] Patrol density varies from a low of 0.07 patrolmen per shift per square mile in Los Angeles County to a high of 4.6 in City "Y"! Since Los Angeles County has the largest proportion of areas that are rarely patrolled, Phoenix, at 0.46 patrolmen per shift per square mile, is probably a better example of a thinly patrolled city. Thus, City "Y" is 14 times more densely patrolled than Phoenix, yet the victimization rate is only about 10 percent less. However, one cannot conclude that patrol density is not closely related to victimization probability. Possible relationships such as these are discussed more fully in our analysis below of a 30-city sample.

Annual arrests (Part I and II) per uniformed patrolman—one measure of police *effectiveness*—also shows little visible relationship to victimization rate. It varies from a low of 22 in City "Y" to a high of about 80 in Los Angeles—a factor of 4. Annual Part I and II arrests per capita varies widely too, from .046 for Los Angeles County (the department with the lowest Part I crimes per capita) to .085 for Los Angeles City, but no relationship with Part I crimes per capita is clearly visible. Although Los Angeles City has the highest Part I arrests per capita, it is only average in Part I crimes per capita.

Note that the entries in Table 3 for police budget per patrol car or patrolman

[4] All per capita input, demand, and output criteria use *residential* population as a base. Since different cities have different proportions of transient or daytime population, the reader should bear in mind that similar comparisons using daytime population might be considerably different.

on three shifts vary from a low of about $43,000 to a high of $180,000. These artificially high values are obtained when the *total* annual police budget is divided by the average number of uniformed patrolmen or patrol cars *on the street* during an average day (three shifts). On the basis of dollars per uniformed patrolman on the force, the values are much lower (from about $15,000 to $27,000). Cost per patrolman or patrol car on the street combines in one measure the *joint* effects of the fraction of the patrol force that is assigned to field duty, the fraction of one-man versus two-man cars employed, and the proportions of the police budget devoted to nonpatrol functions as well as patrol functions such as command-control, clerical, and administration. As stated, this measure is not as revealing as *actual* costs per patrolman or patrol car on the street during an average day, but these data were not available.

Summarizing thus far, we see that for our small sample of six police departments, relevant measures of police inputs, demands, workload, and police outputs show great variability. Furthermore, one can infer only a few significant relationships among these factors. Leaving aside absolute size factors (such as calls for service, crime, patrol strength), the ordinary least-squares regression analysis shown in the Appendix reveals that only two pairs of measures seem to be related: (1) patrol strength per square mile and annual calls for service per square mile, and (2) patrol strength per capita and Part I crimes per capita (victimization rate). It is certainly not possible, given such a small sample, to infer general relationships or guidelines regarding "adequate" or "required" patrol force level (i.e., overall patrol strength per capita or patrol density on the street) from the demands for police service. The data are interesting but very limited and, therefore, inconclusive.

In a subsequent section in this chapter we show the results of a preliminary statistical analysis using both the 6-city and 30-city sample data sets. The purpose is to explore more fully the relationships between patrol force level, crime, and demographic variables.

THE SIX CITIES OVER THE DECADE OF THE SIXTIES

How have the six cities fared over the decade of the sixties? Employing a subset of the measures displayed in the cross-sectional overview above, Figs. 5 through 10 display the variations over time of uniformed patrol strength per 1000 population, reported annual Part I crimes per capita (victimization rate), and two workload measures: calls for service per patrolman and reported Part I crimes per patrolman. For those cities which did not provide data on patrol strength over time, we have substituted total police employees. Although the pattern is somewhat different in each city, there are unmistakable trends of growth in each measure.

Table 4 summarizes the data in the figures by indicating rough percentage of changes in these measures between the early years (1960-61) and late years (1968-69) of the decade.

Assuming, for purposes of discussion, that neither crime reporting practices and procedures by police nor crime reporting rates by citizens have changed over

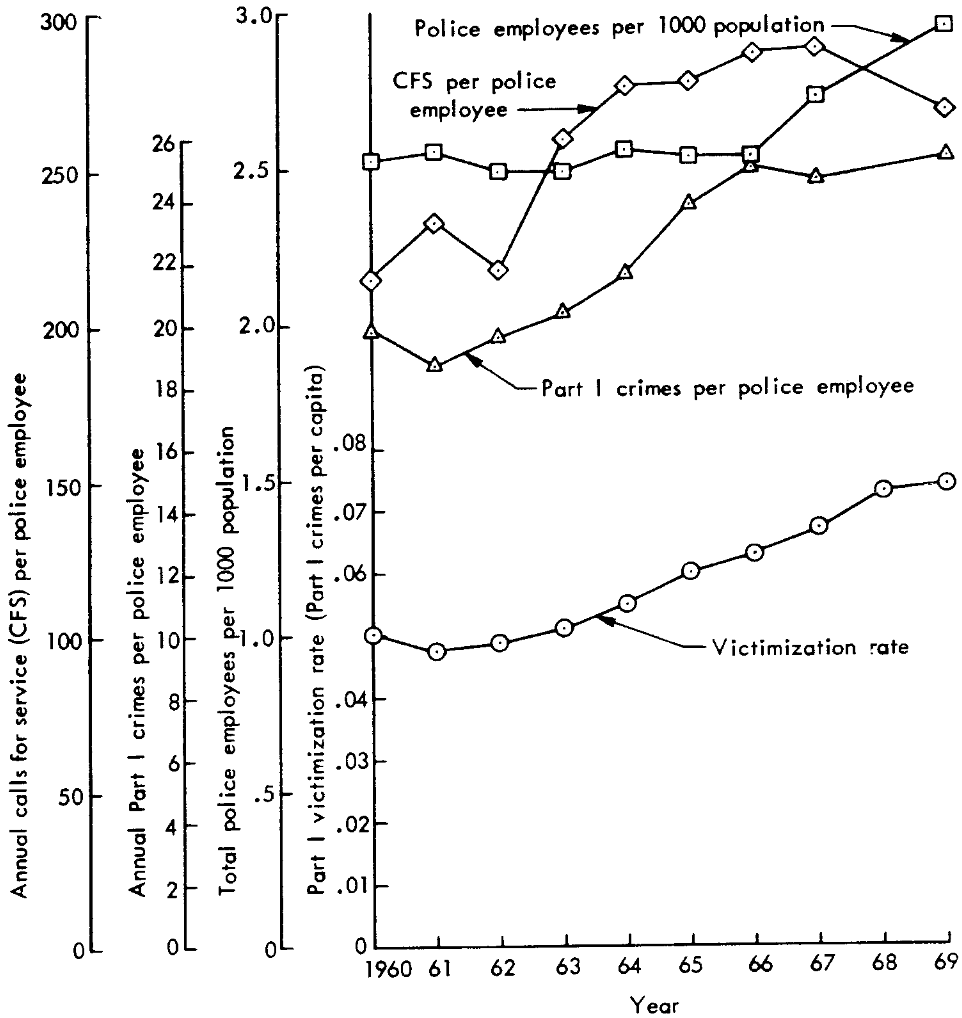

Fig. 5—Los Angeles Police Department (1960-1969)

the decade in each city, we note that reported annual Part I crimes per capita have grown at least 50 percent in two cities and as much as 180 percent in two others. However, *increases in police or patrolmen per capita have not kept pace with reported crime per capita,* although they have outpaced population change by 12 to 43 percent. Workload per patrolman has grown, too, but not as rapidly as has victimization rate. Calls for service increased by 30 to 45 percent and crimes per patrolman increased by 35 to 160 percent. Generally speaking, the relative disparities between growth in demand for police services compared to growth in police resources and

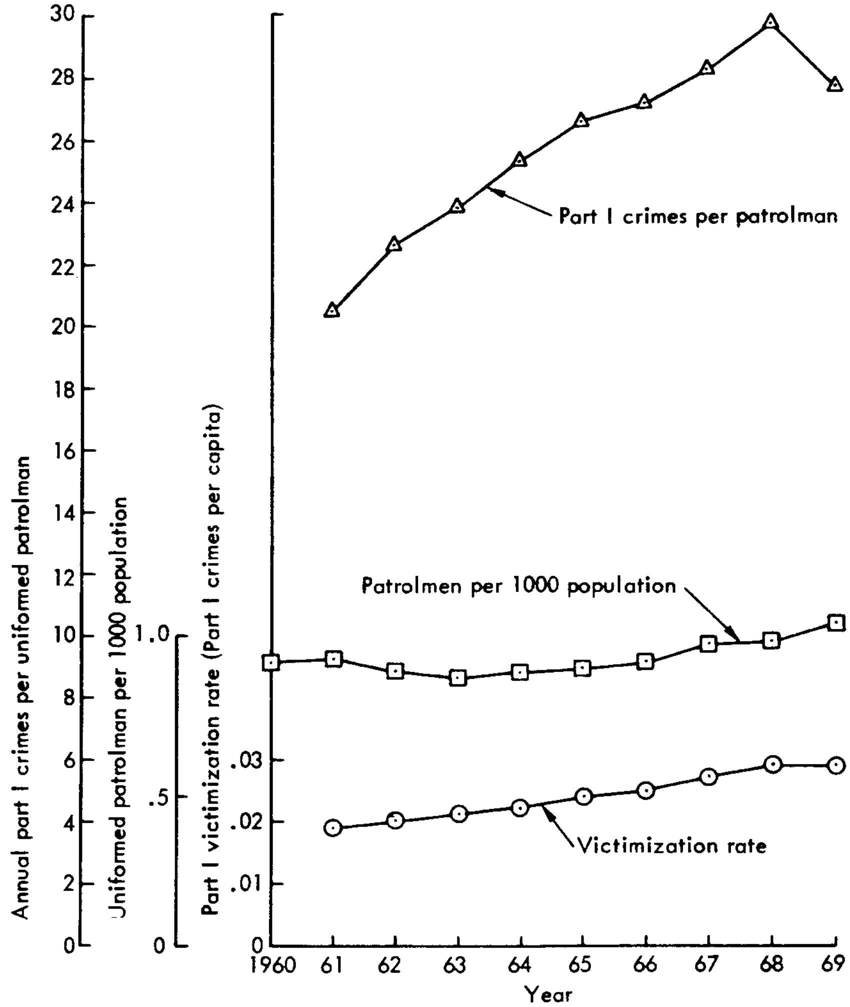

Fig. 6—Los Angeles County Sheriff's Department (1960-1969)

workloads appear to be least in Los Angeles (City and County), whereas these relative disparities are greatest for St. Louis, City "X," and City "Y."

ORGANIZATIONAL AND OPERATIONAL COMPARISONS

Thus far we have focused on intercity comparisons of rough measures of police demand, output, workload, and inputs. In this section we present an overview

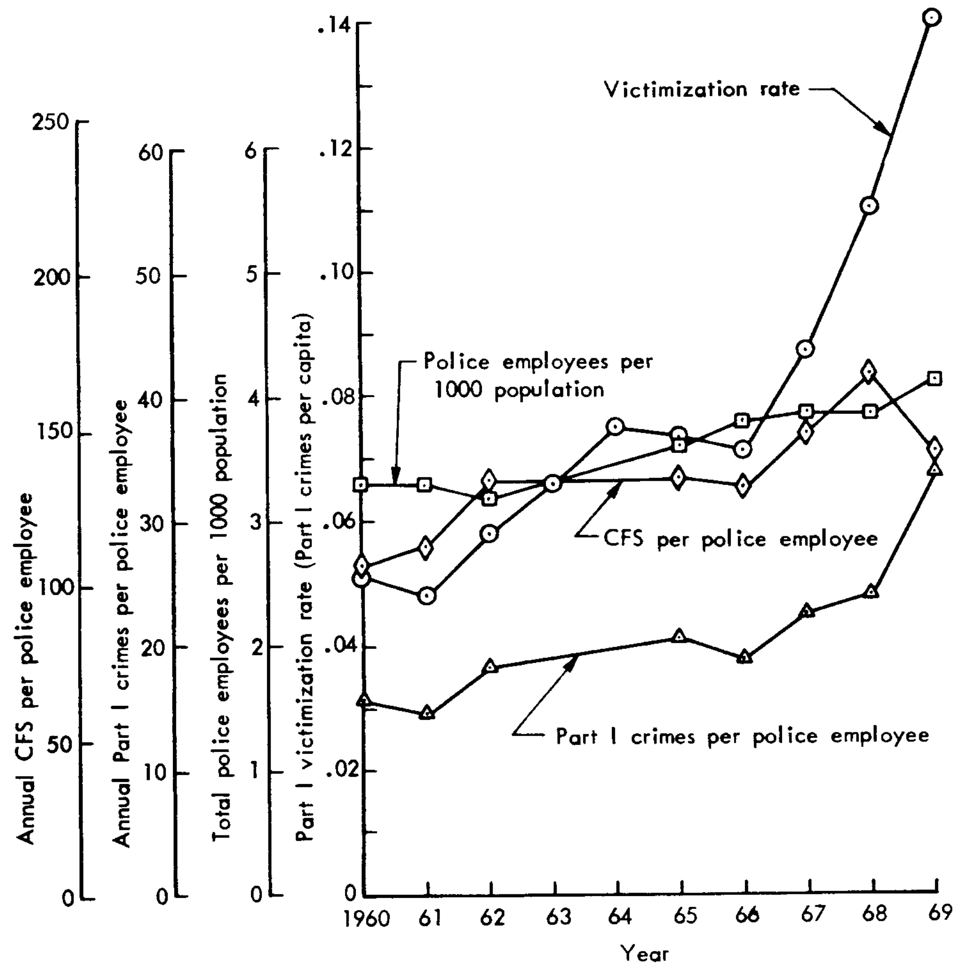

Fig. 7—St. Louis Police Department (1960-1969)

of some of the organizational and operational features of police patrol in the six-city sample.

Table 5 summarizes some of these features. A more detailed description of each police department is contained in the responses to the questionnaires (see R-594-HUD/RC). Notice that all six patrol organizations exhibit a similar geographical command hierarchy. Once the complement of patrolmen in a division (called precinct, district, or station in some departments) is established by top police management, the assignment of patrolmen and patrol cars to beats is made largely by the division commander. That is, beat assignment is an example of decentralized decisionmaking. During a tour of duty or shift, it is generally the division watch

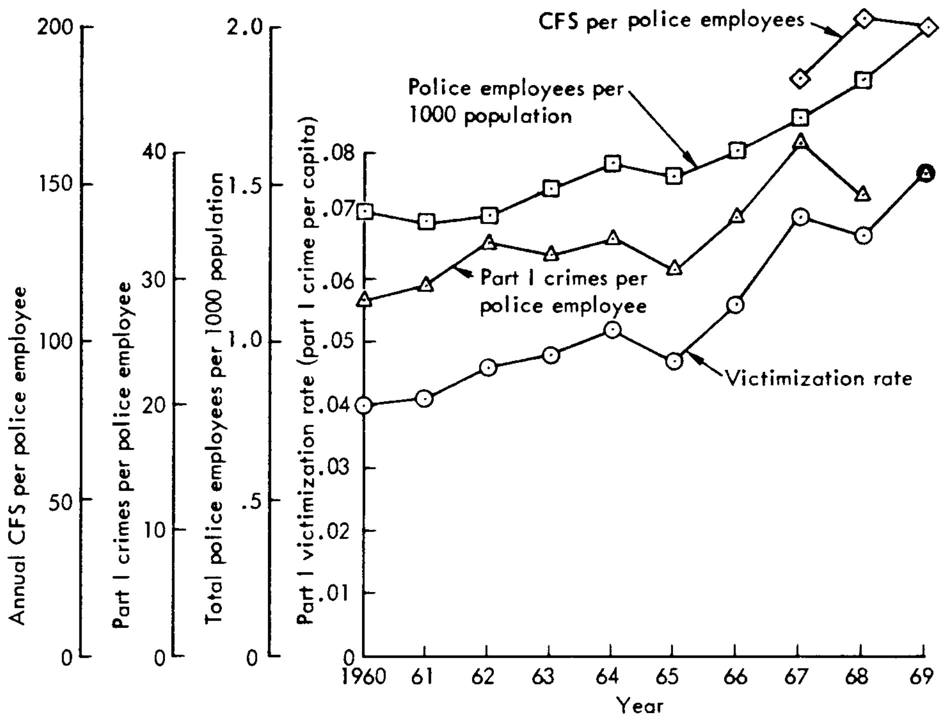

Fig. 8—Phoenix Police Department (1960-1969)

commander who is authorized to reassign men to beats, if the situation warrants. Dispatching operations are usually centralized, although, in one case, two dispatch centers are employed (because of considerations of geography and communications), and in another, a combination of centralized and decentralized dispatching is utilized.

Generally speaking, most departments operate with informal priorities assigned to incoming calls, although some employ more formal priority categories. Serious crimes in progress usually receive first priority, crimes not immediately dangerous receive second priority, and past crimes and incidents receive lowest priority. The circumstances under which no patrol car is dispatched in response to a call generally vary with workload. Again, few departments operate under a formal policy.[5] For example, in this sample, only St. Louis specifies precisely which conditions must be met if a call for service is to be resolved by a report prepared over the telephone.

Table 6 displays various measures of responsiveness of police patrol to calls for services. Note that few departments routinely measure certain delay character-

[5] One example of a department (outside our sample) which did formally and publicly specify the circumstances and categories under which a call would not receive a dispatch is Detroit. Such a policy was employed during 1968 and 1969.

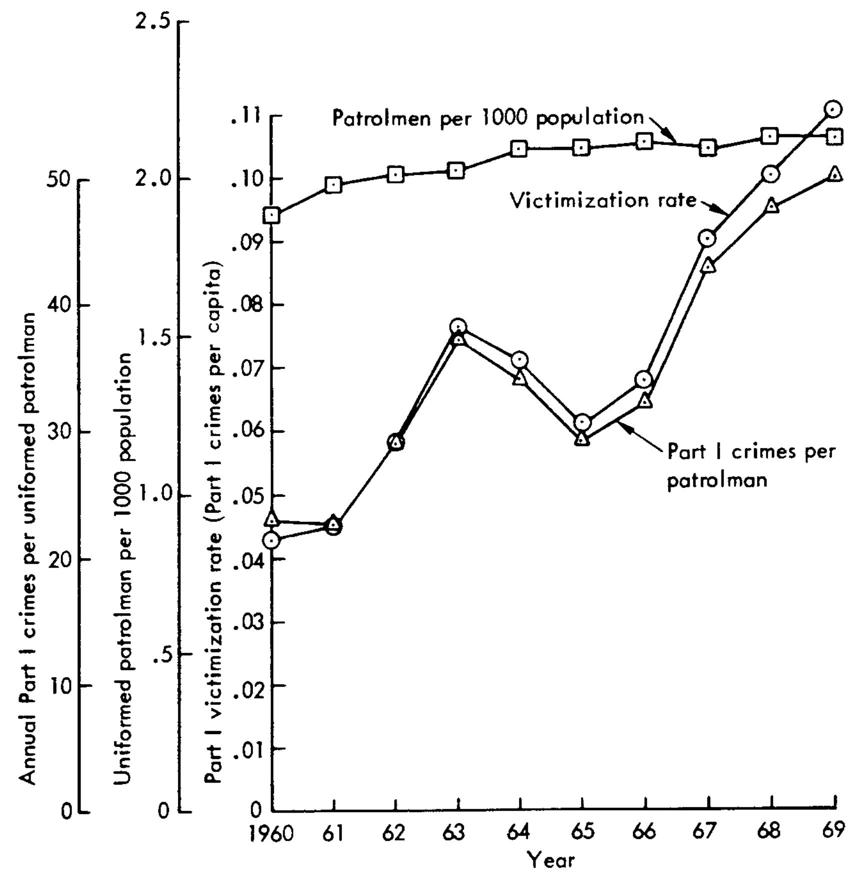

Fig. 9—City "X" Police Department (1960-1969)

istics; these instances are noted. Others have either estimated these quantities in a rough way or have actually measured them in one area of the city; these instances are also noted. Estimates of the average citywide time delay between receipt of a call for service and dispatch of a patrol car vary widely from a fraction of a minute to 6 minutes (the latter figure results from routine measurements in Phoenix). The average time delay is about 2.4 minutes. Travel time varies from 2.5 to 7.5 minutes, with the average being 5 minutes. It is interesting to note that service times do not vary appreciably among cities; citywide average times for crime calls and noncrime calls are 34 and 28 minutes, respectively. It is estimated that about 10 to 15 percent of calls are not immediately dispatchable, due to car unavailability.

The table clearly indicates that some departments simply do not know how responsive their patrol force is in terms of these measures. Cities "X" and "Y" are prime examples. Furthermore, half of the departments simply do not measure travel

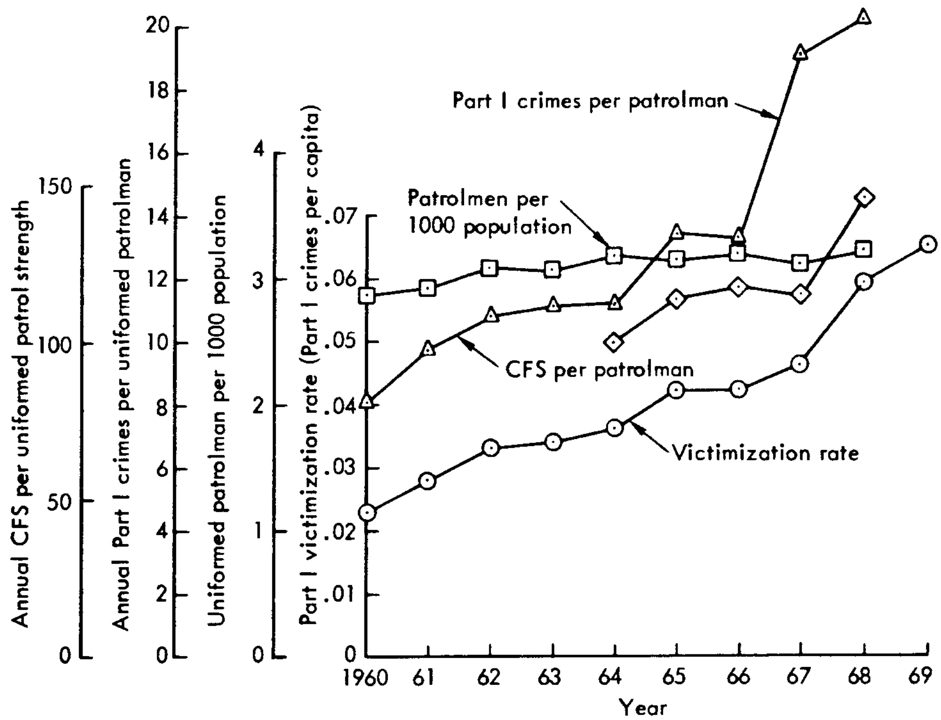

Fig. 10—City "Y" Police Department (1960-1969)

time or the fraction of calls not immediately dispatchable. And of those that have estimated certain responsiveness measures, few have done so in a systematic and reliable way. If these measures are valid criteria for evaluating a patrol force's responsiveness and accessibility (as we have argued earlier), *police departments should institute a systematic and reliable information system to capture these data.* It is not necessary to measure these quantities on a routine basis. In fact, to do so would be wasteful of resources. They need only be sampled intermittently, in all districts, in a way that captures the variation by hour of day, shift, day of week, etc.

Table 7 displays the estimated allocation, by shift, of a patrolman's time between preventive patrol and all other activities. Data are shown for Los Angeles (City and County) and for Phoenix. St. Louis, City "X", and City "Y" do not collect such data. Observe that the fraction of time spent on preventive patrol is *least* during the *high crime hours* of the evening and special shifts. Only 15 to 37 percent of the time is spent patrolling during these hours, whereas comparable figures for the day shift are 25 to 35 percent and for the late night shift are 30 to 50 percent.

We know that, in most cities, crime calls account for a relatively small proportion of the call-for-service workload. For example, in St. Louis, crime calls account for roughly 20 percent of the total occupied time. In New York City, a detailed

Table 4

CHANGES IN DEMAND, INPUT, AND WORKLOAD MEASURES DURING THE SIXTIES

Change in Measure (late 1960s over early 1960s)	City of Los Angeles	Los Angeles County	St. Louis	Phoenix	City "X"	City "Y"
Reported Part I Crimes per capita (victimization rate)	+50%	+50%	+180%	+92%	+132%	+182%
Uniformed patrolmen per 1000 population	+17*	+15	+26*	+43*	+13	+12
Calls for service per patrolman	+30*	N/A	+50*	N/A	N/A	+45**
Reported Part I crimes per patrolman	+35*	+40	+126*	+42*	+117	+160

NOTE: N/A -- Not Available.

*Police employees used because data on uniformed patrol strength were not furnished.

**Over a 4-year period.

study of one precinct revealed that crime calls account for roughly 30 percent of the occupied time.[6] The comparable figure for Phoenix is over 60 percent, but we are of the opinion that part of the large difference may result from differences in defining whether certain call types fall in the "crime" or "noncrime" category.

Thus, accounting for meals, scheduled breaks, court appearances, processing arrestees, crime calls, and the like, patrolmen spend at least as much time providing service on noncrime calls as they do on preventive patrol. The decision to trade off noncrime service for preventive patrol depends on both political factors and the *value* of preventive patrol in deterring and preventing crime. As we have already indicated, the value of preventive patrol is not known with any confidence and it must be determined by careful experimentation. We indicate later that this is one of the basic research tasks necessary to understanding patrol effectiveness.

INTERNAL PLANNING UNITS AND USE OF OUTSIDE CONSULTANTS

All the police departments in the survey operate an internal planning and research unit. This unit generally is responsible either to the assistant chief for administrative matters or directly to the police chief or commissioner. The extent

[6] From unpublished studies of the New York City Police Department by The Rand Corporation.

Table 5

A COMPARISON OF ORGANIZATIONAL AND OPERATIONAL FEATURES OF POLICE PATROL

City	Patrol Hierarchy	Who Assigns to Beat?	Beat Rotation	Who Reassigns during Shift?	Dispatching	Call Priorities	Circumstances for No Dispatch to Call
Los Angeles Police Dept.	Beat or radio car district, division area	Division commander	Permanent for cars in basic car plan; remainder shift with demand	Communications or watch commander	Two dispatch centers	In-progress crimes; crimes not immed. dangerous; past incidents & crimes	Varies with workload and overall situation in city
Los Angeles County Sheriff's Dept.	Beat, station	Station lieutenant	Varies with station Min=1 mo.; Av=3 mos.; Experimental 1-yr assignment in 1 station	Watch sergeant	Communication centralized; dispatch decision-making decentralized	Similar to LAPD	Varies with workload and overall situation in city
St. Louis Metropolitan Police Dept.	Beat, precinct, district, area	District captain	Variable, due to beat deployment system (1 day to 6 mos.)	Captain or watch commander (Lt.)	Centralized	Prompt; stack (high and low priority) similar to above cities	22% of calls resolved without dispatch (larceny under $50, lost articles, property destruction, past incidents
Phoenix Police Dept.	Beat, squad area, district	District commander (Lt.), squad supervisor	Variable; av 18 mos. on beat, 2 yrs. in squad, 3 yrs. in district	District Cdr. (Lt.) for district; squad sgt. for squad area	Centralized	No formal priorities	Information calls. Policy is to dispatch when requested
City "X" Police Dept.	Sector, district	District captain	Variable, but usually permanent	Shift commander (Lt.)	Centralized	No formal priorities	Varies with workload
City "Y" Police Dept.	Sector, district, division	District commander	Permanent beat assignment	District duty supervisor	Centralized	No formal priorities	Rare. During busy nights, fire & "group on street corner" calls not dispatched

Table 6

DELAYS AND RESPONSIVENESS TO CALLS FOR SERVICE

Measure of Responsiveness	City of Los Angeles	Los Angeles County	St. Louis	Phoenix	City "X"	City "Y"	Average over Cities
Time delay between receipt of call and dispatch (min)	<3*	0.5*	2*	6**	N/A	0.3*	2.4
Travel time (min)	N/A	7.5**	N/A	5**	2.5*	N/A	5
Service time (min)							
Crime	29*	33**	48*	25**	N/A	N/A	34
Noncrime	32*	30**	34*	15**	N/A	--	28
Percentage of calls not immed. dispatchable	10-15*	N/A	15**	N/A	N/A	<1% hi priority; <10% low priority	--

NOTE: N/A -- Not Available.

*Estimated.

**Measured.

of the unit's influence in the department and the decisions which it affects vary from department to department. In one city (City "Y") it apparently influences most major policy and operational decisions in a major way. In others, its influence is more narrowly confined. However, in most of the departments it affects decisions involving resource allocation, manpower scheduling, the development and implementation of new information systems and command-control systems, and the selection and evaluation of new equipment. In addition, most planning units direct and monitor the activities and progress of outside consultants.

Civilians are employed heavily in all but two of the planning units. And one of these two departments plans shortly to add civilians to its planning unit. Generally speaking, in staffing planning units with either sworn personnel or civilians, efforts are made to select personnel with college training in relevant fields such as business, economics, mathematics, law, and computers. However, only St. Louis and City "Y" currently employ personnel who are highly trained and experienced in operations research, cost-benefit analysis, and related fields.

All of the departments surveyed utilize outside consultants for a variety of purposes. Some employ consultants, such as the International Association of Chiefs of Police (IACP), in studying proposed alternative organizational changes. The purposes and issues most commonly addressed by outside consultants are the design and implementation of information retrieval systems (crime reporting, wants and warrants, stolen car files, etc.), management information and command-control systems,

Table 7

HOW A PATROLMAN'S TIME IS ALLOCATED

Activities	Percentage of Time*				
	Day	Evening	Night	Special Shift	Average over Shifts
LOS ANGELES PD					
Preventive patrol	34	32	29	30	31
All other (response to calls, observation arrests, breaks, court appearances, etc.)	66	68	71	70	69
LOS ANGELES COUNTY SHERIFF'S DEPARTMENT					
Preventive patrol**	35	37	51	--	41
All other**	65	63	49	--	59
PHOENIX PD					
Preventive patrol	25	15	35	15	23
All other	75	85	65	85	77

*These data are not available for St. Louis, City "X", and City "Y".

**One week's activities at one station only.

and resource allocation and workload prediction (crime and calls for service) schemes.

Our view is that all large police departments should build a capable, in-house, analytic planning staff including at least one *civilian planner who is highly trained and experienced in operations research, cost-benefit analysis, and the use of computers.* In addition to planning and conducting in-house research and analysis and facilitating the implementation process of innovations within the department, an in-house civilian planner could interpret police policy and needs (as articulated by top police management) in terms relevant to the consultants. Additionally, the civilian planner could be invaluable because he could guide, critically evaluate, and interpret the work of outside consultants. To attract and retain such key personnel, police departments must recruit from the better university graduate schools, private industry, and research organizations; they must pay competitive rates; and, most importantly, they must provide the key civilian planner with *ready access to the police chief.*

THE USES OF DATA AND COMPUTERS

All of the six police departments surveyed have access to, and utilize, a computer. Two of the six departments (Los Angeles County and City "Y") have exclusive access, whereas the remainder share at least one computer with other city agencies. Two of the departments (Los Angeles County and City "X") utilize the computer as a simple information retrieval system for police management. Arrest, crime, incident, narcotics, clearance, personnel, and traffic reports comprise the bulk of the data stored for retrieval by most of the cities. The other cities also use the computer for additional purposes. Information systems of various sorts are used operationally; these include wants and warrants searches (Los Angeles, City "Y"), stolen-vehicle files (City "Y"), field reports (Los Angeles, City "Y"), and modus operandi (M.O.) files. Los Angeles City, St. Louis, and Phoenix also use the computer to predict crime incidence and call-for-service workload and to allocate patrol resources by district, shift, day of week, etc.[7]

Generally speaking, most departments collect a vast amount of data, much of which is never translated into machine-readable form. But some departments do translate a large proportion into machine-readable form; yet these files are infrequently used or, if used, are often ineffective in furthering police objectives. Thus, resources are wasted on computer applications which are currently marginally effective. Also, since the utilization of city computers is generally quite high, opportunities for making more effective use of computer resources are foregone. For example, one city computerized its M.O. files about 1955. That police department's experience has been that detectives found the file not very useful because the turnaround time is long, the most recent data contained in the file are several weeks old (and therefore of questionable value), the M.O. data incorporated in the file are often incomplete, and, finally, very old data in the file are not regularly purged (so that "hits" often include irrelevant, ancient information). Thus, it would seem wise to design, implement, and test an operational information system before cluttering the files with little used, marginally effective computer applications.

Some data clearly should be collected, categorized, and aggregated in computer-readable form on a routine basis. Crime, arrest, call-for-service, traffic, and manpower deployment data are prime examples. There are *other data categories that need only be sampled on an intermittent basis, thus conserving resources.* Examples of such categories are data bearing on patrol responsiveness and accessibility (such as the various components of response time, fraction of calls for service for which a dispatch was not immediately available, patrol car speeds, number of intersector dispatches),[8] *true* crime rate (i.e., victimization survey data), and survey data designed to elicit from the public its degree of satisfaction with the services provided by police.

We have argued in Chapter II that there is a set of criteria which have wide

[7] Chapter IV discusses the allocation and prediction methods in use by these (and other departments), as well as improved methods not yet tested operationally.

[8] See Chapter IV for a more detailed discussion of allocation methods which require collection of such data.

applicability in evaluating the effectiveness, equity, and efficiency of alternative police patrol programs. It turns out that very little of the data currently collected and filed (in either manual or computer-readable form) by police departments are relevant to these criteria. Therefore, although some departments collect data which are rarely used, most departments fail to collect certain data which would be extremely useful in providing relevant inputs into many of the major police patrol allocation and tactical decisions. We illustrate this state of affairs below.

CURRENT DATA DEFICIENCIES FOR ESTIMATING PREFERRED EVALUATION CRITERIA

Table 8 shows the extent to which the police departments surveyed now collect (routinely or intermittently) the necessary data required to estimate values of the nine evaluation criteria recommended in Chapter II. Note that only reported crime data are available in all the cities surveyed. In all cities, reported victimiza-

Table 8

DATA DEFICIENCIES VIS-A-VIS PREFERRED EVALUATION CRITERIA

asures	City of Los Angeles	Los Angeles County	St. Louis	Phoenix	City "X"	City "Y"
Patrol arrest rate (by crime category)	N/A	N/A	N/A	N/A	N/A	N/A
Charging rate by crime category	N/A	N/A	N/A	N/A	N/A	N/A
Reported victimization rate (by crime category and citizen group)	P/A	P/A	P/A	P/A	P/A	P/A
Reported crime (by crime category)	A	A	A	A	A	A
Percentage of citizens satisfied with police patrol service	N/A	N/A	N/A	N/A	N/A	N/A
Response time components*	P/A	P/A	N/A	P/A	N/A	N/A
Preventive patrol frequency	N/A	N/A	N/A	N/A	N/A	N/A
Hours of preventive patrol per suppressible crime	N/A	N/A	N/A	N/A	N/A	N/A
Resources expended	N/A	N/A	N/A	N/A	N/A	N/A

NOTES: N/A -- Not Available; P/A -- Partially Available; A -- Available.

*See Table 6.

tion probability can be estimated from available data, but only by crime category and not by citizen group. As we indicated in Table 6, only some components of delay and responsiveness are available in three cities, while the remaining three do not include any of that type of data. None of the cities collects the data necessary in estimating the remaining six criteria.

A PRELIMINARY STATISTICAL ANALYSIS OF POLICE STRENGTH, CRIME, AND DEMOGRAPHIC FACTORS

All police departments have the problems of determining the overall force level, the patrol manpower level required, and effective allocation of patrol forces to each shift and division. Estimating the effectiveness of police in influencing crime rate, in responding to calls for service, and in apprehending suspected criminals is central in addressing these problems. Moreover, the number of assigned officers or patrol cars is probably only one of the many factors influencing crime rate. For example, other criminal justice agency programs, changing population characteristics within a city, or differences in population characteristics among cities should explain some of the differences in crime rate. Such demographic factors as population density, proportion of the population in particular age groups, median income level, educational attainment, mobility, and so on are prime variables to be explored.

As we indicate in Chapter V, the final determination of the effect of police manning level on crime must come from controlled experiments in the field. But the experiments should be preceded by preliminary statistical analysis so that the experiments can be more productive of both information and crime reduction.[9] These statistical analyses can be performed on citywide data using data from a set of cities for a given year. Such analyses are relevant to the issue of the proper patrol force level. When similar analyses are performed on precinct or division data from a single city, the analyses are relevant to the allocation of patrol resources to divisions. In this section we address the force level question using data from several cities for a single year.

An inherent difficulty of most statistical analysis is the inability to distinguish between cause and effect. Because rising crime rate may result in additional police manpower allocations, the two may appear positively correlated. But this does not mean that additional police *cause* additional crime.

The Appendix contains the details of the preliminary statistical analyses

[9] The President's Crime Commission specifically discussed this point in recommending that police departments should undertake data collection and experimentation programs to develop statistical procedures for manpower allocation. The Science and Technology Task Force also did a preliminary statistical analysis to predict the number of reported serious crimes in each of the Los Angeles Police Department's divisions as a function of the number of patrol officers assigned to the division, in order to estimate the change in the number of serious crimes associated with the reallocation of a patrolman from one division to another. See *The Challenge of Crime in a Free Society*, a report by the President's Commission on Law Enforcement and Administration of Justice, Washington, D.C., February 1967, p. 257.

performed in this study. Only the results and implications are presented in this section.

Three data sets were employed in the statistical analysis: the six-city sample, and a 30-city subset,[10] for the years 1960 and 1968, of the 37 cities comprising the Kansas City Police Department annual survey of municipal police departments.

A statistical regression analysis of some of the variables in the *six-city sample* revealed statistically significant relationships between several pairs of variables.[11] It is not surprising that cities with larger populations seem to generate more calls for service, and cities with a large number of calls for service seem to have larger patrol forces. Such relationships are not unexpected because they stem essentially from the size factor. More interestingly, two relationships were found for variables expressed in per capita or per square mile terms. On a per shift basis, higher densities of calls for service (per square mile) seemed to be associated with higher patrol densities (per square mile). Also, higher victimization rates (i.e., number of reported Part I crimes per capita) seemed to be associated with higher patrol strength per capita. However, little can be concluded from these relationships because of the small sample of six cities. At best, these relationships are indicative of those which should be explored using larger samples of cities. We have used the six-city statistical analysis as a starting point for analyzing the 30-city sample data set. Unfortunately, the 30-city data sets contain no information on call-for-service volume; therefore, numbers of reported serious crimes and victimization rates are the only available measures of demand or output.

For the 1968 30-city data set, we postulated relatively simple relationships between police strength and factors such as serious crime (in particular, reported Index crimes), population, and area. On a per capita basis, relationships between police per capita on the one hand and reported Index crimes per capita and population density, on the other hand, were postulated. For the 1960 data set we postulated richer models, using 1960 Census data. Since crime is a complex phenomenon, thought to be affected by various social and economic conditions, we explored the possibility that crime incidence and hence police strength, on an absolute or per capita basis, are related also to basic demographic factors such as age of population, poverty, and mobility. Several studies have shown, for example, that criminals in urban areas are more likely to be young, poor, and from minority groups. Victims of serious crimes are also more likely to be poor and from minority groups. Thus, it was hypothesized that additional police would be employed in cities with higher crime rates and with higher proportions of disadvantaged populations. With this in mind, we selected, in addition, four demographic variables for inclusion in the 1960 data analysis. They are percentages of poor in the population (i.e., those families

[10] Seven of the 37 cities were omitted because they had a significant proportion of the patrol force on foot. In our analysis, one of the relevant measures of police presence tested was patrol cars on the street per shift. If a significant fraction of the patrol force is on foot in a given city, this would introduce bias if that city were included in the sample.

[11] There may be significant correlations between other variable pairs, but limited resources did not permit us to test all of the interesting combinations. Also, pairwise regression is only of limited value because it ignores probable effects of excluded variables. Because of the small data sample, it was not possible to postulate more complex multivariate relationships.

earning less than $3,000 annually), nonwhites, young people (i.e., between the ages of 15 and 29), and a mobility variable (defined as the percentage of the population that had moved into their domiciles within two years of the 1960 Census, that is, since 1958).

What, if anything, can be concluded from the statistical regression analysis of the 1968 and 1960 data sets? First, not surprisingly, it is clear that crime measures and police input measures can be better estimated statistically using *absolute* measures (such as annual number of crimes, number of police, population, and area) rather than measures expressed in *per capita* terms. This is true for both 1968 and 1960. Second, 1968 crime and police measures can be more adequately modeled than comparable 1960 measures, basically because, compared to 1968 data, 1960 crime data were relatively uncorrelated with police input and demographic factors. We speculate that one possible explanatory factor is that reporting practices and procedures for serious crime may have been less uniform among cities in 1960 than in 1968.

In the analysis of the 1968 data, for which we had no socioeconomic data, we found that *absolute* measures of crime and police inputs could be modeled quite well using a technique known as two-stage multivariate regression analysis. The model postulated that serious crime is related to police strength and population, and police strength, in turn, is related to crime and police budget. Attempting to model crime and police inputs on a *per capita basis,* we found that two-stage estimation techniques were less successful than ordinary least-squares techniques. However, the ordinary least-squares technique was quite successful. For example, 72 percent of the variation in police per capita could be explained by reported Index crime per capita and population density.[12]

Because of lack of significant correlation of crime per capita with every other variable tested in the 1960 data set, we found that all of the models postulated in terms of *per capita* police and crime measures were unsuccessful predictors. This was true whether ordinary least-squares or two-stage least-squares regression techniques were used. It was also true whether socioeconomic variables were included or excluded. However, in employing models in which the crime and police input measures were expressed in *absolute terms,* we found that the ordinary least-squares regression analysis succeeded in a limited way. About 56 percent of the variance in crime could be explained using only population and area variables, whereas the police strength variable alone explained only 44 percent. A similar situation held for police strength—about 85 percent of the variance in police strength was explained using population and area variables, whereas the crime variable alone explained only 44 percent. Moreover, adding one or more socioeconomic variables, such as percentages of poor, nonwhite, young, and a mobility factor, generally did not materially improve the explanatory power of the models, and rarely did we find that any of these variables were statistically significant. This is not to say that socioeconomic variables are not related to crime and police measures, but that the

[12] See Model 10 in the Appendix.

particular set of data (30 medium-sized cities in 1960) did not reveal strong relationships.

Thus, although our preliminary statistical analysis shows mixed results, we believe that multivariate regression techniques are useful in testing theories and models of the relationships between the levels of law enforcement inputs and crime.[13] Because of lack of data, our analysis omitted a number of other variables which may be material. For example, *calls for service* should importantly affect police workload and, hence, should affect overall police strength. Other omissions are the possible effects of *other criminal justice system variables* on crime, such as sentencing practices of judges, recidivism rates, number of ex-convicts residing in the area, and correctional programs. Missing, too, are explicit data on the *public's attitudes and views on crime and law enforcement;* these views should affect the kinds and levels of services provided by the police, the relative emphasis given to enforcement of various criminal statutes, and the level and deployment of police strength.

We strongly believe that it is worthwhile to invest resources in more comprehensive analyses of this sort.[14] It would be more advantageous to have highly disaggregated time-series (perhaps on a division or neighborhood basis) data for a city. That is, one should search for and/or collect a consistent set of data including police inputs, crime, socioeconomic factors, other criminal justice inputs, and public attitudes in several cities, on a neighborhood level, which is available yearly over several years. With such data available over time, it should be possible to include rates of change in the variables and time lag effects in the models, thus, hopefully, greatly improving the accuracy of estimation. Analyses of such data would be relevant to both the force level issue and the issue of allocating fixed resources by time and place in a city.

[13] Again, our preliminary analysis reinforces observations and suggestions made by the Science and Technology Task Force of the President's Crime Commission. We have performed such analyses on data relevant to police force level decisions, whereas the Task Force's analysis was more relevant to allocation of fixed, overall patrol resources to divisions within a city.

[14] Our quick survey indicates that the literature dealing with modeling of crime is not extensive and the literature on modeling of law enforcement inputs, excepting the Crime Commission work, is essentially nonexistent. Belton M. Fleisher explored the relations between some economic variables and delinquency (see B. M. Fleisher, *The Economics of Delinquency*, Quadrangle Books, 1966, and B. M. Fleisher, "The Effect of Income on Delinquency," *American Economic Review*, 1966). Using cross-sectional data he explored the relationship between income and delinquency, where the measures of delinquency were arrests per thousand males less than 25 years of age and number of court appearances of males aged 12 through 16, for property crimes. Using time series (longitudinal) data, he explored the relationship between unemployment and similar delinquency measures, but this work did not attempt to relate crime and economic variables to law enforcement inputs.

IV. METHODS FOR ALLOCATING POLICE PATROL RESOURCES

In this chapter we discuss present methods, employed in the six departments surveyed, for allocating police patrol personnel. The benefits and limitations of these methods are considered, as well as alternative methods now available but not yet in use. Finally, we propose an approach that should offer a substantial improvement.

THE DECISIONS TO BE ADDRESSED

Methods to be discussed in this section are aimed at providing guidance for the three basic types of decisions in patrol program management mentioned at the outset:

1. The size of patrol force necessary to provide satisfactory levels of service and protection to the public.
2. The deployment of a given number of patrolmen by time and place.
3. The operational rules, tactics, and command-control hardware to be employed by the patrol force. Examples are priority policies and "stacking" rules for calls for service and the costs and benefits of car location systems.

All of these decisions depend on the definition of a satisfactory level of protection and service; a useful working definition cannot now involve effectiveness measures such as true crime rates, number of crimes prevented, or the total social and economic impact of crime, since none of these quantities is easily measurable, nor is the relation of patrol force levels and tactics to these quantities known. Instead, proxy measures of effect that are relevant to both the particular jurisdiction and decisions under consideration must be chosen. Earlier, we suggested several such measurable criteria.

PRESENT METHODS: BENEFITS AND LIMITATIONS

A wide variety of techniques are currently in use. The techniques discussed below are command discretion, hazard formulas, and three operational computer-assisted methods.

Command Discretion

In some large police departments no formalized quantitative procedures are employed either to substantiate requests for changes in police force size or to aid in deploying men to duty tours and patrol districts. Two of the departments surveyed were in this category.

When no quantitative aids are used to assist in the allocation of police manpower, much information contained in readily available data cannot be effectively exposed because of the sheer volume and detail of the data. Without technical aids, relatively well-known but complex relationships between manpower levels and measures such as response time and patrol frequency cannot be incorporated into the decision.

On the positive side, we stress that judgment and discretion must of necessity play a significant role in every deployment decision, since community, institutional, and police morale considerations often govern the decisions as much as do considerations of effectiveness, efficiency, and equity. The quantitative methods primarily relate to the latter factors and should serve only as useful *inputs* to decisions.

Hazard Formulas

Currently, many departments employ "hazard formulas"[1] as a partial basis for assigning manpower. Generally speaking, such formulas subjectively combine (into a single number) all factors thought to be relevant to determining the need for police services. Men are then assigned to districts in proportion to the relative "hazard" of each district. The list of factors included varies from city to city but often includes reported crime, number of radio calls, arrests, number of business establishments, area, and population. The hazard rating for the district is arrived at by multiplying each factor by a weight (indicating the importance of the factor in relation to other factors) and adding together all weighted factors.

Hazard formulas used in two different cities are given below.

Example 1. Hazard for district i =
percent of city's *Part I crimes* occurring in district i
\+ percent of city's *Part II crimes* occurring in district i
\+ percent of city's *custody arrests* occurring in district i
\+ percent of city's *injury accidents* occurring in district i
\+ percent of city's *ambulance runs* occurring in district i
\+ percent of city's *fires* occurring in district i
\+ percent of city's *police "services" rendered* in district i

[1] O. W. Wilson, *Police Administration*, 2nd Edition, McGraw-Hill, 1963.

+ percent of city's *population* in district i
+ percent of city's *population density* in district i
+ percent of city's *area* in district i
+ percent of city's *road miles* in district i
+ percent of city's *licensed premises* in district i
+ percent of city's *store doors* in district i
+ percent of city's *schools* in district i.

Example 2. Hazard for district i =
[5] [percent of city's *selected crimes and attempts* in district i]
\+ [4] [percent of city's *radio calls handled by radio cars* in district i]
\+ [3] [percent of city's *felony arrests* in district i]
\+ [1] [percent of city's *misdemeanor arrests* in district i]
\+ [1] [percent of city's *property loss* in district i]
\+ [1] [percent of city's *injury traffic accidents* in district i]
\+ [1] [percent of city's *vehicles recovered* in district i]
\+ [1] [percent of city's *population* in district i]
\+ [1] [percent of city's *street miles* in district i]
\+ [1] [percent of city's *population density* in district i].

Notice that in the first example all factors have equal weighting, whereas in the second example crimes, radio calls, and felony arrests are considered more important than the remaining factors.

Compared to command discretion, this technique is beneficial in that it requires police administrators to specify explicitly the elements of police workload and their relative importance. Geographically disaggregated data, in addition to the overall hazard scores, provide useful inputs to the deployment decision.

When these formulas evolved more than 20 years ago, they were the best methods available, since neither the data nor the mathematical theory were well developed enough to support better methods. Such is not the case today.

The hazard formula method is unsatisfactory for several reasons. The weighted linear (additive) combination of the many hazard factors neither reflects the highly complex interactions among the factors nor gives individual attention to any single factor. As typically used, hazard formulas reflect past conditions and data for a district rather than current and predicted future conditions for day and shift as well as district. More importantly, existing hazard formulas do not relate meaningful measures of effectiveness to operational policies. That is, the hazard formulas in use fail to provide a police administrator with such policy-relevant information as the response time of the patrol force, or the probability that a patrol car will detect a crime in progress. Also, the formulas are not relevant for determining the total size of the patrol force required to satisfy certain service-level criteria.

In 1967, the British Home Office published what might be called a "hazard formula" relating police strength ("establishments" in British lexicon) to several variables.[2] In all but two of the 29 British police departments, the actual police strength and the police strength predicted by the formula were within 2½ percent of one another. The formula is as follows:

[2] R. Catstree, T. J. Kempton, *Assessment of Police Establishments by Formula—Proposed Yardstick for City and Borough Forces*, Report No. 3/67, Police Research and Development Branch, Home Office, London. The coefficients were determined using linear regression techniques.

$$\text{Police strength} = \frac{\text{residential population}}{1000} + \frac{\text{acreage}}{350} + \frac{\text{road mileage}}{2.9} + \frac{\text{recorded crime}}{40}.$$

The formula was apparently intended to point out those departments with police forces that were significantly different from a "typical" force.

The Phoenix Method

In Phoenix, the hazard formula concept is employed in an innovative and helpful manner. The basic hazard is defined as the delay plus travel plus service times for all calls during a given time period in a given place. Cars are deployed by district, shift, and day of week in proportion to the fraction of the total citywide hazard predicted to occur in that time period and geographic area. A computer is used to extrapolate the data of the previous ten weeks on the number of incidents and elapsed time (defined as delay time plus travel and service time) for each shift, day of week, and one-fourth-square-mile geographic area.

The three constructive innovations are (1) the use of predicted calls in the formula rather than calls actually experienced in the past, (2) the use of elapsed time rather than just volume of calls, and (3) an allocation simultaneously by day, shift, and district rather than by district alone. However, preventive aspects of patrol are not addressed. Another limitation is that all calls (serious crimes in progress, past crimes, sick call, cat in tree) receive the same weighting.

The St. Louis Method

The most advanced operational method of patrol force deployment currently in use has been developed and applied in St. Louis.[3] In their scheme, demand for police services is predicted by hour and geographic area, using projections based on past demand data with modification for weekly and seasonal variations. A simple mathematical technique is then used to estimate the number of patrol cars needed to immediately answer, without dispatching delay, 85 percent of the predicted incoming calls for service in each geographic area by day and four-hour time period. The remainder of the patrol force is assigned to preventive patrol.

To predict call-for-service workload,[4] exponential smoothing of past dispatch data is employed. Total calls for service in eight categories[5] are predicted for each

[3] Allocation of Patrol Manpower Resources in the St. Louis Police Department: an experiment conducted under Office of Law Enforcement Grant No. 39, Vols. I and II, St. Louis Police Department, July 1966.

[4] Number of calls requiring the dispatch of a patrol car.

[5] High severity crimes against person, theft, destruction of property, fraud, sex offense, general misconduct, traffic, and others.

small geographic area (approximately 10 square city blocks). Total weekly demand is first estimated, taking into account a multiplier for seasonal factors gleaned from historical dispatch data. The hourly demands for service are estimated by assuming that the estimated weekly demand follows a typical pattern over the hours of the week. In effect, the exponential smoothing technique estimates future calls by "averaging" the volume of calls experienced in past weeks, with the more recent weeks' data being given the most weight. The seasonal adjustment factor is also estimated using exponential smoothing. This prediction technique is simple to use on a computer and requires as input data the number of calls for service in each geographic area by hour. Exponential smoothing is only one of several possible prediction methods. The St. Louis Police Department is currently investigating the utility (and methods) of incorporating weather data in the predictions.

To enable the number of cars needed in each area to be estimated, the length of time required to service each of the eight types of calls is also estimated, using exponential smoothing of past service time data.

Only one criterion of satisfactory police response is used. *The number of response cars is set so that less than 15 percent of all calls will incur a delay in dispatching due to car unavailability.* The remaining cars, typically a small fraction of the patrol force, are then assigned to preventive patrol activity. Those cars on preventive patrol may be asked to respond to urgent calls if the entire response force in the area is busy.

The number of response cars to be assigned to each police district is estimated by applying queueing theory. The predicted calls for service are assumed to arrive at random times (i.e., arrive according to a Poisson probability distribution). It is assumed that (1) calls are serviced by any one of a number of cars, C, in order of call arrival, (2) the average length of service is equal to the value predicted from past data, and (3) service times obey an exponential probability distribution. The number of cars, C, in the mathematical model is varied until the probability of the average call having to wait before a car is dispatched is approximately 0.15. That number of cars for which 15 percent of the calls in a district are delayed is then the recommended response force size. The "15 percent delayed" figure was set by the St. Louis Police as representing a satisfactory level of service, but it can be easily changed if desired.

The St. Louis efforts are a commendable beginning toward improving techniques of police patrol deployment. However, their deployment methods are severely limited in that the *sole criterion* used in the mathematical technique to determine the required number of *response cars* (i.e., the split of the patrol force into response and preventive units) is the fraction of calls that cannot be answered immediately by a response car. Requirements for *preventive patrol* are not explicitly considered when assigning cars, and the question of the relative value of a car on response and one on preventive assignments is not addressed. Also, certain policy issues cannot be addressed, such as the determination of the appropriate size of the total mobile patrol force.

The LEMRAS Method [6]

Based on the St. Louis method, the IBM Corporation has developed a computer program which it will lease to police departments for $350 per month. The Los Angeles Police Department, for example, has already installed the system in one division and plans to implement it citywide. Because of its proprietary nature, the LEMRAS computer coding is not readily decipherable (at least by the LAPD), so that changes desired by local police may be difficult to implement without assistance from IBM.

While the LEMRAS and St. Louis techniques are basically similar, the IBM product does include a more flexible model of the manner in which calls are serviced: namely, priority service for certain types of calls is allowed if desired. Being so closely related, these two methods offer essentially the same benefits and suffer from the same limitations. The marketing of this technique by the IBM Corporation thus has mixed blessings. We believe that better methods (described below) could be developed rather easily. The introduction of the LEMRAS patrol allocation programs in major police departments therefore may occur at the time that those programs are superseded by improved allocation methods.

* * *

In a later section we present a method which has several distinct advantages over any of those currently in use—and we expect it would cost only negligibly more than current computer-assisted methods to operate.

EXAMPLES OF MANPOWER ALLOCATIONS USING DIFFERENT METHODS

In our survey, we found no systematic quantitative methods currently in use for supporting a police department's requests for patrol manpower. Intercity comparisons on the basis of police per capita, per call for service, per crime, etc., were presented in Chapter III. As was pointed out, wide variation in some of these input measures from city to city was not accompanied by any obvious closely related variation in output measures, such as crime per population. The uncertainties surrounding the relation of criminal justice system inputs to system effectiveness are probably largely responsible for the lack of any accepted quantitative methods to provide guidance on patrol force size.

In deploying a given patrol force, moreover, two cities in the survey reported that patrolmen were allocated to districts strictly on the basis of hazard ratings. In neither case did the average number of patrol cars actually deployed in each district during the sample one-week time period closely match the hazard rating for the district. Figure 11 is an illustration of (1) the actual allocation of 185 patrol cars

[6] LEMRAS stands for Law Enforcement Manpower Resource Allocation System.

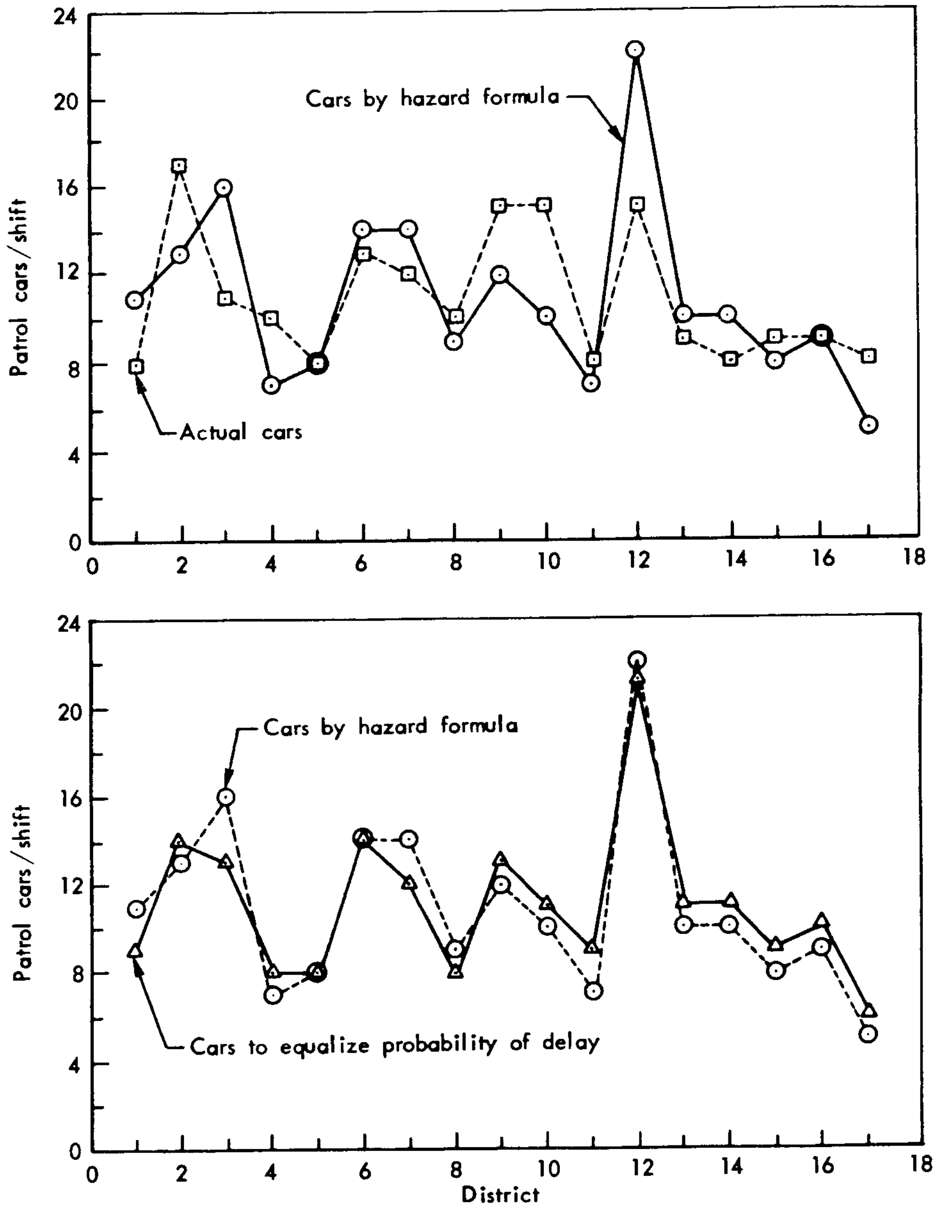

Fig. 11—Patrol car allocation method comparison

within one city, (2) the allocation of 185 cars which would result from using that city's hazard formula, and (3) the allocation of the same number of cars to equalize the probability of delay in dispatching in each district due to car unavailability (the St. Louis criterion). The average difference between the actual allocation of 185 cars and the allocation that would result from their hazard method is 24 percent. The biggest change occurs in district 12 where the hazard formula indicates 22 cars would be needed and 15 were actually allocated. The number of cars actually allocated represents the average number of regular district (excluding special tactical unit) cars on the street for a shift during a one-week period. We caution that without an in-depth look at the data, no firm conclusions should be drawn. However, the data do suggest that cars actually on duty do not conform closely with (presumably) intended allocation by hazard formula.

As can be seen in Fig. 11, the number of cars allocated to a district during an average shift to equalize the probability of dispatch delay due to car unavailability is somewhat different from the "hazard" allocation of the same number of cars. The average difference is 12 percent, with the biggest difference (3 cars) occurring in district 3. The average difference between the actual deployment and deployment that results in equalizing the probability of dispatch delay is 16 percent.

The need for police services varies significantly by day of week, shift, and geographic area. Flexibility is best maintained if deployment decisions are made by time and area simultaneously. Until the introduction of a fourth platoon in New York City last year, manning varied significantly only by geographic area, since manning by shift was relatively constant. Thus, while an 8 to 1 ratio of demand for police service was common between late evening and early morning hours, the comparable ratios of patrol resources allocated to those times were only about 1.2 to 1.[7]

As an example of how dramatically different allocations can be when allocation methods are changed and varying demands are considered by day, shift, and district simultaneously, consider one of the cities surveyed on a slow day (Thursday) as compared to a busy day (Saturday). Figure 12 presents the percentage of difference between the actual deployment of car-shifts using the city's "hazard" method and the deployment of the same number of car-shifts (a car-shift is one car for an 8-hour tour of duty) in a manner to equalize the probability of delay in each area and time period. We are using the single criterion of delay probability for illustrative purposes only because this city is currently implementing the LEMRAS deployment method. We prefer deployment methods which employ multiple criteria. In Fig. 12, the average difference in number of cars allocated is 30 percent. The maximum difference in any district was 120 percent. The number of cars in all districts (city-wide) for each day and shift are compared in Table 9. Of the 158 car-shifts, 92 were shifted between Thursday and Saturday, 64 were shifted between districts on the same day and shift, and 2 were intershift differences on the same day. This example suggests that significant differences can result from a change in allocation procedure and criteria.

[7] Unpublished reports by The Rand Corporation of work for the New York City Police Department.

Table 9

ALLOCATION OF PATROL CARS BY DAY AND SHIFT

Day and Shift	Actual Cars	Cars To Equalize Probability of Delay
Thursday		
Night	110	112
Day	189	150
Evening	245	190
Saturday		
Night	133	193
Day	172	201
Evening	254	257
Total	1103	1103

In Fig. 13 we present data from our survey on various measures of workload or responsibility per car for one city. There is wide variation among districts. The cars in various districts of this city clearly do not have equal workloads, as judged by any of the simple criteria displayed. Resident population per car ranges from 3,632 to 16,034. (Daytime populations were not available.) Average assigned road miles per car ranges from 9.07 to 30.83. Average Part I crime per car-shift ranges from 0.3 to 1.1. Percent time spent on calls for service per car-shift ranges from 20 percent to 39 percent (assuming 30 minutes per call). Thus the percentage time free for preventive patrol and other noncall-answering duties ranges from 61 percent to 80 percent in this city. We could not evaluate the relative need for preventive patrol in each district in terms of suppressible crime from the data available.

Figure 14 compares police inputs and several measures of demand for police services for each district of one city surveyed. For each district, we give the percentage of the city's population, Part I crime, calls for police service, and average number of cars allocated per shift, as well as the actual victimization rate (i.e., Part I crimes per capita).

Regarding the issue of the *equitable* distribution of patrol services, for illustrating extreme cases, consider the very significant changes in deployment if cars were to be allocated solely in proportion to any one of the variables displayed in Fig. 14. In the city whose data are illustrated, actual cars allocated seem to be more closely related to the presentage of call-for-service volume than any other one of the potential criteria illustrated. To change this would mean that certain low-priority calls would receive poorer service and that workload (in terms of calls per car) would become more unbalanced. Clearly, it is not possible to achieve all concepts of effectiveness and equity simultaneously. The tradeoffs will depend on local situations and preferences.

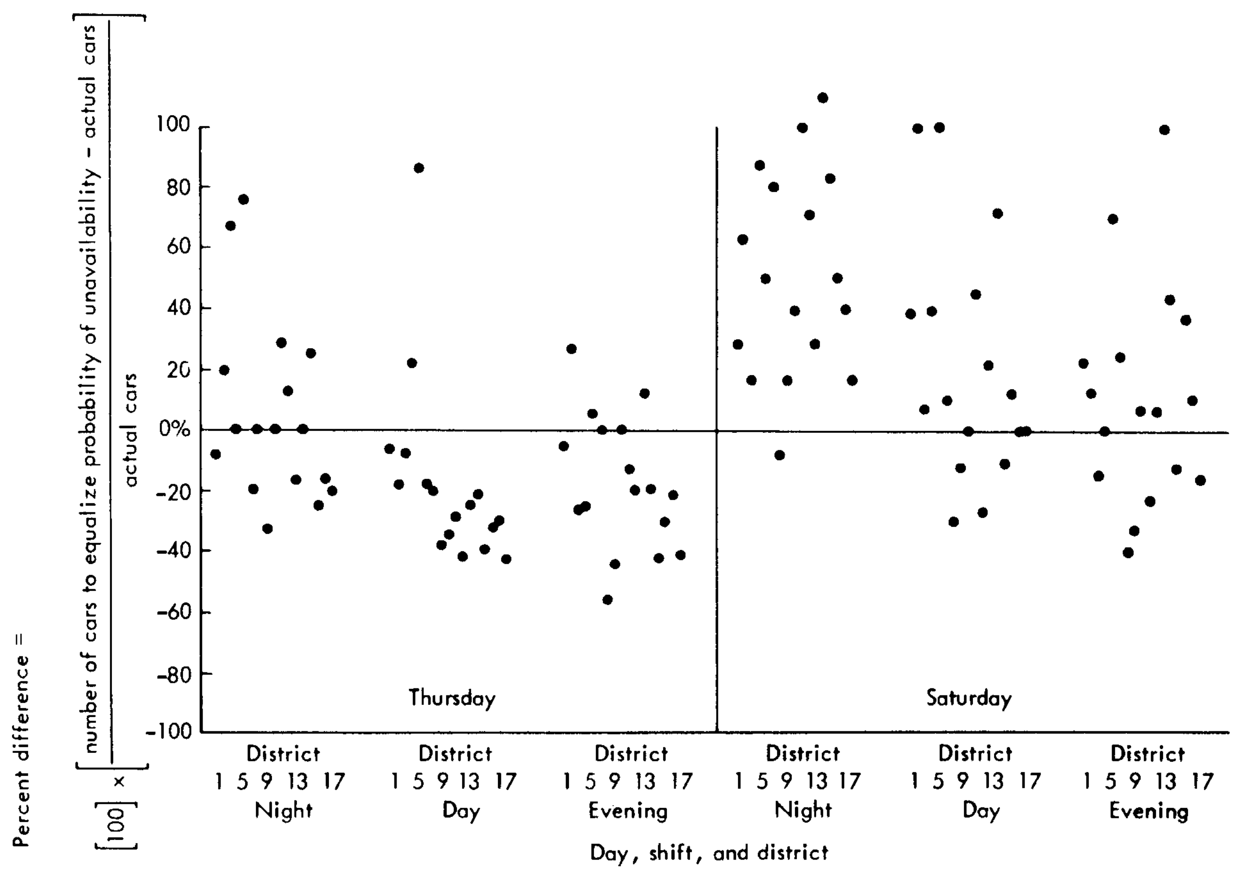

Fig. 12—Difference between cars allocated to equalize probability of car unavailability and cars actually allocated

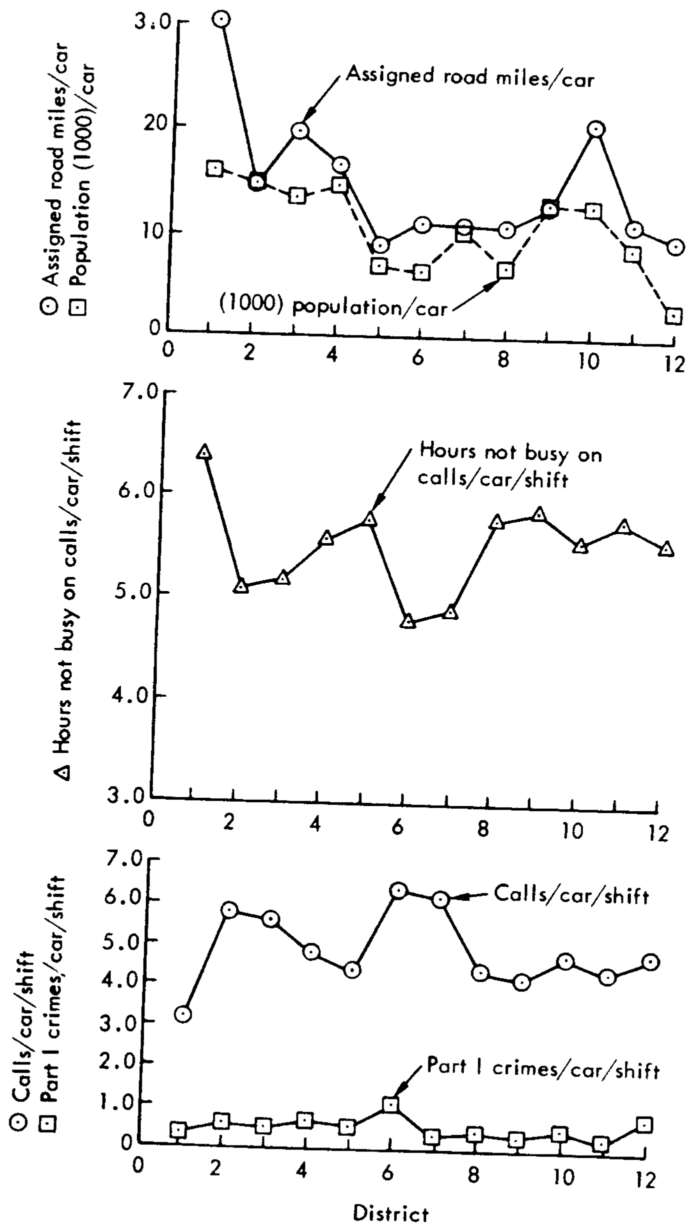

Fig. 13—Patrol car workload

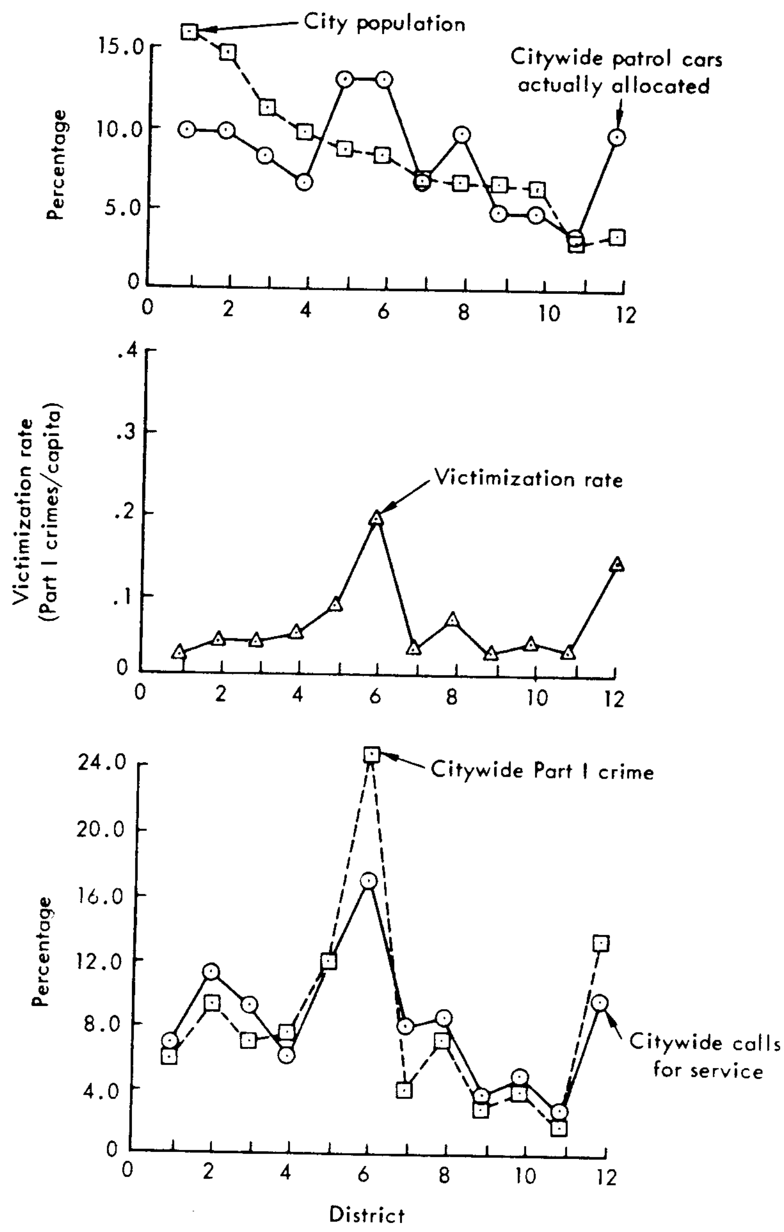

Fig. 14—A comparison of demands and police inputs by district

IMPROVED ALTERNATIVE APPROACHES

Two patrol allocation methods, mathematically feasible but different from any now in use, possess logical advantages over those described above.

The first method involves the use of *multiple criteria with each measure treated separately.* Probabilistic models are used to predict measures such as dispatch delay, average response time, preventive patrol frequency, and the amount of time available for preventive patrol, as a function of the number of patrol cars in an area. Then mathematical programming techniques are used to specify the best deployment of patrol resources such that all measures in each district are at specified acceptable levels or better.

A second method involves the simulation of patrol activities on a computer and would be useful in situations where some critical part of the patrol operation cannot be mathematically analyzed in a manner useful for policymaking.

As examples of research and development in the above methods, we will outline below some of the work of Dr. Richard C. Larson, of the Massachusetts Institute of Technology, a consultant to The Rand Corporation. While his work is probably the most advanced in the field, it has not yet been fully developed, experimentally tested, and applied.[8]

The descriptions of the two methods that follow include the data requirements, details of issues that may be addressed, and outputs available from the methods.

Later in this chapter we shall suggest some potential improvements. For a detailed review of other work in the field, refer to Albert Bottoms' work.[9]

The Deployment Analysis and Allocation Method

This approach, which is fully programmed for computer use, involves analytic models that predict the performance of a specified manpower level and police deployment in terms of dispatch delay, average response time, patrol frequency, and amount of time available for preventive patrol. The measures used are flexible and any set of criteria which can be analytically related to patrol manpower may be utilized. This method applies dynamic programming[10] as its mathematical allocation technique. It allows the police to determine the manpower necessary to provide acceptable levels of service in terms of each of the measures, and also to allocate a specified patrol force size to neighborhoods, by time of day and week, so as to yield the highest service level obtainable with the given force. This technique is more comprehensive than the one used in St. Louis, in terms of the multiple criteria which may be used, and because it addresses the preventive as well as the response aspects of patrol.

[8] R. C. Larson, *Models for the Allocation of Urban Police Patrol Forces*, Technical Report No. 44, Operations Research Center, Massachusetts Institute of Technology, November 1969.

[9] A. Bottoms, *Allocation of Resources in the Chicago Police Department*, Vols. I and II, Final Report on research conducted under Grant No. 195, from the Office of Law Enforcement Assistance, U.S. Department of Justice, November 1969.

[10] R. E. Bellman and S. E. Dreyfus, *Applied Dynamic Programming*. Princeton University Press, 1962.

In its current form, the method can be used *to evaluate the effect of a given police manning level and deployment* in terms of the expected number of preventive patrol hours for each outside crime, the expected frequency of patrol in the neighborhood, and the average time required to travel to the scene of a reported incident or call for service.

The method can also be used *to determine the manning level necessary during each time period and in each neighborhood to meet set levels of performance* which are measured in terms of the three quantities mentioned above, plus the added constraint that a certain minimum number of patrol cars be present at all times in the neighborhood.

This method can serve *to allocate a given number of men to patrol precincts and shifts such that satisfactory service levels are maintained* and, in addition, the average delay in dispatching due to car unavailability will be minimized.

The minimum levels of services provided may be set by the police or community and may vary with the neighborhood or time of day, depending on conditions. The various service level criteria used in this method are flexible but currently include the following:

1. The average number of preventive patrol hours for each outside crime shall not be less than a specified value in each neighborhood.
2. The average frequency of patrol (which is related to outside crime-detection probability) in a neighborhood shall not be less than a specified value.
3. The average time required to travel to the scene of a reported incident or call for service shall not exceed a specified value.
4. The number of patrol cars for each neighborhood shall not be less than an administratively set minimum.

The use of these measures of service is based on the assumption that additional preventive patrol and reduced response time have a positive effect on crime deterrence and on increasing the chance of apprehending a criminal near the scene of a crime. The existence of such an effect and its actual degree are not known and should be investigated experimentally. Until the relative value of assigning men to increased preventive patrol time as opposed to reducing response time is known, the deployment problem may be resolved by allocating patrolmen to satisfy subjective "target levels" of various criteria of patrol effectiveness. The four measures of service used in the current model are clearly arbitrary and open to revision to suit the local situation.

Procedurally, the number of cars necessary to provide minimum levels of service on each criterion for each district and time period are calculated. The remainder of the force is then deployed (using dynamic programming) to minimize the dispatching delay due to unavailability of free cars.

For this technique, the data needed for each command and shift to which police are to be assigned are:

- Area.
- Patrollable street miles.

- Average travel speed of a patrolling car by time of day and day of week.
- Average travel speed of a responding car by time of day and day of week.
- Volume and distribution over time of various types of calls for service.
- Volume and distribution over time of reported outside crimes.
- Average total service time for each type of call.[11]

The outputs of the deployment analysis and allocation method are:

- An analysis of the present deployment giving (a) expected response time, (b) expected frequency of preventive patrol, and (c) expected total number of preventive patrol hours.
- A reallocation of current manpower to satisfy all constraints on levels of service and to minimize delay in dispatching cars due to temporary unavailability of a free patrol car.
- An analysis of the reallocation of manpower in terms of (a), (b), and (c) above.
- A determination of the minimum force level necessary in each patrol district to just satisfy each service level contraint.

In a computational exercise using this model and data from New York City, the predicted variation in service levels among precincts was greatly reduced, while average time delay in dispatching due to car unavailability was cut from about 4 minutes to less than 1 minute by reallocating the same citywide level of manpower. In addition, all measures of acceptable service level were met, whereas they were not all satisfactory when the existing allocation of manpower was used.[12]

The method could easily be generalized to include the use of other measures such as gearing preventive patrol hours to victimization rates or placing limits on the maximum acceptable response times for different types of calls for service. Various police agencies could undoubtedly generate other measures.

Other objectives could be used in deploying the remainder of the force, such as minimization of response time or maximization of the probability of on-scene arrest throughout the city.

Simulation of Patrol Deployment

The simulation technique allows much more detailed and complicated questions to be investigated than can be satisfactorily addressed by any of the analytical techniques described earlier. The price paid for this increased flexibility and generality is that longer computer processing time is required.

The advantage of the simulation method comes from its ability to investigate the implications of rather complicated allocation and deployment strategies and tactics by use of a computer before expensive field tests are begun. The relatively

[11] It is our impression that these data could be obtained or estimated to the required degree of accuracy without excessive difficulty and expense.

[12] Unpublished reports by The Rand Corporation of work for the New York City Police Department.

inexpensive computer studies would then point the way toward desirable improvements which could be tested experimentally in the city.

One such simulation, developed by Larson,[13] is organized in the following manner. The city or region to be studied is broken into small geographic areas from which demands for service may originate. The crimes or other calls for service occur at random and may be of any number of priorities. The rate at which incidents occur depends on the time of day, week, and year. The geographic cells may be grouped to represent single- or multiple-car beats and districts. In this computer simulation, when an incident is brought to the attention of the police, an attempt is made to dispatch a police car. Almost any set of *priorities and dispatching rules* may be employed in the computer program. Rules on "*stacking*" *calls, assigning cars from other areas, and relocation of cars to perform preventive patrol* can also be very flexible. To enable the simulated testing of various *car locator systems,* the dispatcher may be given information of any degree of accuracy on the location of the incident, time of dispatch, location of dispatched car, time of arrival, and completion of work at the scene of the incident, and may also collect statistics on the location, status, and workload of each car in the city.

The data needed for this model are of the same general nature as those required for Larson's analytic deployment model but are of finer detail, i.e., data are needed for each geographic cell rather than each car beat or patrol district.

Since the simulation technique is extremely flexible, outputs on almost any quantity of interest to police planners may be obtained. A sampling of statistics that may be recorded are listed below:

- Total time from reporting to arrival at the scene of an incident.
- Total service time required for a call.
- Workload of each patrol car.
- Travel time of a car to the scene of an incident.
- Number and waiting time of calls that are not immediately dispatched.
- Fraction of calls in a sector that are answered by the car assigned to the sector.
- Frequency and type of intersector dispatching.
- Amount and time of preventive patrol coverage for each geographic area.

The deployment simulation method can also be used to explore such questions as the following: How does changing the size and shape of patrol car beats affect operation? What are the effects of assigning several patrol cars to one (merged) beat? What are the relative cost and response time benefits of introducing patrol car locator systems versus simply adding more patrol cars? In what way is system operation improved by redeploying patrol cars dynamically? What are the effects of different priority dispatching schemes? Which rules on intersector dispatching seem advantageous? What are the interrelationships between dispatching rules and preventive patrol coverage?

[13] Larson, op. cit.

A PROPOSED APPROACH

During the past twenty years, mathematical aids to resource allocation have developed to a point where they are potentially useful for police patrol planning. It is not necessary to use computers in conjunction with these decisionmaking aids, but their use would enable alternative estimates of effective deployments of patrol manpower to be made in a few minutes. This means that deployments can be dynamic, if desired, to respond rapidly to changing needs for police service.

Three of the cities surveyed are utilizing some of the available mathematical techniques to aid in making patrol deployment decisions. No city is exhausting the available tools. This does not seem to be because of a decision to limit their use, or because of recurring costs of using those techniques, but because a "ready to use" package is not currently available, and because the police rarely have any employees who have sufficient relevant (e.g., mathematical) training to understand, interpret, use, and communicate the results of such techniques. It is our impression that police administrators in most of the cities we surveyed understand that analytical techniques and analytically trained personnel may have high potential payoff, but the individual police departments are unable, for budgetary reasons, to initially develop that potential.

Throughout this chapter we mentioned several desirable attributes of methods for assisting decisionmaking on patrol force strength, deployment, and operational policies and tactics. In summary, to be of maximum possible value, such methods should:

- Provide answers rapidly.
- Use data that can be readily obtained.
- Allocate on the basis of predicted future conditions and demands rather than past conditions.
- Use several evaluation criteria so that several policy-relevant aspects of each proposed manpower allocation can be adequately evaluated.
- Focus separately on each criterion rather than on a conglomerate measure.
- Provide the capability of allocating and deploying resources by day, shift, and district rather than by district only.
- Be relevant to decisions on force size and deployment for preventive patrol as well as for response to calls for service.
- Provide the capability of evaluating alternative operational policies, tactics, and command-control hardware.

After analyzing all available major techniques, we find that no one method has all of the desirable attributes. However, the combination of the good qualities of the St. Louis method and Larson's Deployment Analysis and Simulation Methods would come close to possessing all of the desirable attributes.

We suggest the simulation method as a valuable aid to decisionmaking on new patrol operational policies, tactics, and command-control systems. The method can be employed most advantageously prior to expensive field experimentation.

We suggest the following approach to aid decisionmaking on patrol force strength and its deployment by neighborhood, day, and shift. The steps in the approach are:

1. *Prediction of the incidence of crime and calls for service,* by type, for each geographic area and desired time period. These would be relevant to both decisions on current deployments and the number of additional patrolmen needed in the near future. The St. Louis technique would be one feasible approach.

2. *Specification of a set of criteria and the desired target levels of performance* for each such measure. The criteria and target levels should be made explicit by officials of the local police jurisdiction. Any set of criteria which can be analytically related to patrol manpower can be utilized.

3. *Estimation of the number of men required to achieve various target levels of performance.* Analytic methods are available for relating number and deployment of patrolmen to measures such as average or maximum response time, percent of calls not immediately dispatchable, preventive patrol frequency, hours available for preventive patrol, or probability of on-scene arrest. Unfortunately, basic knowledge is not available for relating manpower to arrests, crime, and public order. That basic knowledge deficiency is the weakest element of every available method. However, relating manpower to responsiveness and patrol coverage, as this suggested approach would, is an important step forward.

4. *Allocation of patrol manpower.* Quantitative techniques, known as mathematical programming, can be used to specify the deployment of a given patrol force, by time and place, to achieve certain specified levels of service in terms of each criterion. A particular overall patrol force level might not provide sufficient manpower to meet minimum acceptable service levels for all criteria. In that event, the method can be employed using various potential patrol force levels to determine the minimum force level required to meet all minimum service levels. In this way, the approach also can be used to address the patrol force strength issue.

* * *

The approach outlined above, combining the more desirable attributes of existing methods, is sufficiently flexible to meet the needs of a variety of police departments. A police department might choose not to use all of the measures mentioned above or to add criteria such as percentage of calls that cannot receive an immediate dispatch due to car unavailability. A flexible approach is taken where any criteria may be used as long as the effect of patrol manpower levels and deployments on those measures can be predicted.

This approach is more comprehensive than any of those presently in use. The overall improvement would come from the combination and simultaneous use of crime and call-for-service prediction techniques, multiple criteria, target levels for each criterion, quantitative methods for estimating the tradeoffs between manpower levels and performance measures, and finally, mathematical deployment algorithms.

This suggested approach logically seems to promise significant improvements, although our resources were too limited to demonstrate this contention in a quantitative fashion. We have no doubts that the mathematical techniques and approach are valid and that operational versions of this method can be developed which are sufficiently flexible to be applicable to a large number of police departments. The benefits to be derived will come from police decisions based on new information not currently being sifted from the data potentially available, and from deployments which are more effective and equitable than those which can be made without the use of advanced resource allocation techniques.

V. AREAS OF NEEDED RESEARCH AND EXPERIMENTATION

We believe that there are significant knowledge gaps which make it impossible to allocate, as rationally as should be, the more than $1 billion devoted annually to police patrol programs. Because of these knowledge gaps, police administrators currently must plan principally in terms of *input measures* (such as number of patrolmen on the street or number of patrol hours) although what they are trying to affect are *output measures* of police effectiveness (such as true crime rate, apprehension rate, and speed and quality of service in response to calls for service). These knowledge gaps are one of the most important factors limiting the development of effective aids to police patrol decisionmaking.

In identifying these knowledge deficiencies and areas of needed research on police programs, we limit our attention to resource allocation and usage. Our suggestions are intended as expansions of certain rather general recommendations made in the area of resource allocation by both the Police and the Science and Technology task forces of the President's Crime Commission in 1967. In discussing police planning, the Police Task Force[1] suggested that crime trends be studied and that experimental projects be devised to test police techniques on a limited scale and under controlled conditions. The Science and Technology Task Force[2] recommended that police departments develop appropriate statistical procedures for manpower allocation, by time and by geography and also suggested that the entire police command-control function be reexamined in the light of new technology, including an examination of the extent to which preventive patrol deters crime, and how response time can be reduced. In another sense, our comments expand on a discussion of gaps in research contained in a 1968 Institute for Defense Analyses report regarding a national program of research on law enforcement and criminal justice.[3] That report included the following priority projects, in light of current research gaps: analysis

[1] The President's Commission on Law Enforcement and the Administration of Justice, *Task Force Report: The Police*, U.S. Government Printing Office, Washington, D.C., 1967, p. 49.

[2] The President's Commission on Law Enforcement and the Administration of Justice, *Task Force Report: Science and Technology*, U.S. Government Printing Office, Washington, D.C., 1967, p. 25.

[3] A. Blumstein, et al., *A National Program of Research, Development, Test, and Evaluation on Law Enforcement and Criminal Justice*, Institute for Defense Analyses, Arlington, Virginia, prepared for the Law Enforcement Assistance Administration, U.S. Department of Justice, November 1968.

and experimentation with preventive patrol strategies and techniques; analysis of factors leading to apprehension of criminals; and improving the allocation of criminal justice system resources by time, place, and function.

We also suggest that research and experimentation be undertaken to identify the *value of various levels and types of preventive patrol,* to provide information on the *effect of the speed and types of response to a call for police service,* and to *predict crime and the volume of calls for services* so that police can be recruited and deployed based on accurate knowledge of the need for police service in each geographic area and time period. Finally, we suggest that *improved methods for deploying patrol manpower* (which were described in Chapter IV) be tested experimentally, modified (if indicated by test results), and implemented.

Preventive Patrol

The relationship between police preventive patrol activity and crime prevention, deterrence, and on-scene criminal apprehension is not well known. It seems reasonable that, *ceteris paribus,* crime should decrease as preventive patrol intensity increases. However, even that belief in the value of preventive patrol is not universally held. The Director of Planning in one major city which we surveyed asserted that preventive patrol was of "no value." While many people might accept the statement that crime and preventive patrol time are inversely related, the quantitative degree of the relationship is still unknown. To allocate resources effectively between preventive patrol and other types of police activity, police administrators need to be able to evaluate each activity in terms of output, or measures of effect. For each type and amount of preventive patrol they need to know how much crime is prevented and how many criminals are likely to be apprehended. They also need to know how much crime is merely displaced to other locations and time periods by preventive patrol. It is intuitively reasonable, but not as yet verified, that preventive patrol affects some types of crime more than others. Such information, along with predictions of where and when various types of crime are likely to occur, would be useful in allocating preventive patrol effort spatially and temporally. The relative effectiveness of various tactics of preventive patrol (e.g., conspicuous or covert presence, continued presence or intermittent saturation of an area, one- or two-man cars, etc.) also are not known. In short, between one-third and one-half of all patrol time is devoted to preventive patrol and the police cannot specify with confidence what effect it has on crime and criminal apprehension. In such a situation, police administrators cannot know if resources are being allocated effectively. Analytical and experimental studies are needed and could result in very substantial changes and improvement in the use of police manpower.

Experiments aimed at understanding the relationship between police patrol inputs and performance criteria such as crime rate are fundamental but very difficult to design and evaluate. There are potential evaluation problems in estimating what crime would have been in the absence of experimental changes in the patrol program. Despite those difficulties, we feel that the relationships sought are so fundamental to better decisionmaking on patrol programs, that this class of "activity-effect" experiments should be pursued.

Given the generally large variability in reported crime with time and neighborhood, we suspect, for statistical reasons, that large variations in preventive patrol force size and tactics will have to be tested if their effects are to be evaluated during a short experiment of a year or less. These preventive patrol experiments would also have to be designed to test to what degree, if any, crime is displaced to surrounding areas.

If major changes in effectiveness measures, such as crime and arrest rate, are observed before and during such an experiment, it is necessary to know how much of the change is in true crime as opposed to reported crime. Since the police know only of reported crime, and since changes in crime reporting rate, for any crime category, might occur because an experiment is in progress, victimization surveys are necessary. A Hawthorne effect might arise—i.e., perhaps police will keep better records because an experiment is in progress; or, if more preventive patrol is introduced, victims might tend to report more crimes because it is easier and more convenient to find a policeman. A victimization survey prior to and during an experiment would reveal, in a rough way, whether the reporting rate of certain crimes[4] had changed significantly and how much the true crime rate had changed. Analysis of the data from such surveys might indicate methods of improving crime reporting by citizens.

In an analysis of a patrol manning experiment, designed and implemented in New York City prior to The Rand Corporation's studies of the Police Department, we encountered many of the difficulties we have described here. No victimization surveys had been taken. The record-keeping procedures in the test precinct were different from those in the rest of the city. The citywide crime reporting system was changed significantly only a few months prior to the experiment, resulting in a large (about 70 percent) sudden rise in reported crime. We could not compare community attitudes before and during the experiment, since our involvement with the test precinct was limited to the period after the experiment. Thus, we were able to observe that statistically significant changes in reported crime did occur for some crime categories and not for others, but were unable to judge whether or not the true crime rate changed because of increased preventive patrol.

The experimentation, if successful, could have high payoffs in that it could generate information on the relationships between patrol programs and their effects on crime, criminals, and the general population, and thus enable allocation and deployment of patrol resources in many departments to be made on a more rational and informed basis than is currently possible.

Response to a Call for Service

The quantitative relationships between speed and type of police response on

[4] A victimization survey could not be expected to reveal true levels of crimes without victims (e.g., gambling, narcotics abuse, prostitution), since many participants in such crimes cannot be expected to respond with candor and honesty.

the one hand, and crime rate, deterrence of crime, probability of an on-scene apprehension, availability of witnesses, and citizen satisfaction, on the other hand, are not known. Knowledge of this sort, if available, should influence and significantly change decisions on the number and deployment of patrolmen for response to calls for service, and the priorities assigned to various types of calls.

The decision on what proportion of one- or two-man cars to deploy greatly affects police responsiveness and accessibility as well as the manpower required. While personnel safety has often been advanced as the argument for two-man cars, the data necessary to support that argument have not been systematically collected. The use of one-man cars, coupled with a policy of two-car response to certain types of calls, may be no more dangerous than two-man cars; at the same time, it nearly doubles the effective patrol force size for the same cost.

Prediction of Crime and Calls for Service

Predictions of crime and police workload have short-term utility in aiding the deployment of men and cars and longer-term utility in making estimates of new recruits needed to meet required future force levels. Such workload predictions are also necessary in evaluating patrol experiments.

The St. Louis and Phoenix prediction methods employ only past crime and call-for-service data in making short-term predictions. A comprehensive comparison of the predictive quality of those two methods and other available techniques has not been conducted. However, St. Louis is evaluating the desirability of incorporating noncrime factors which are thought to influence the number of crimes and calls (such as weather, holidays).

The successful evaluation of the results of "activity-effect" experiments requires a means of detecting whether a new experimental patrol program activity has an effect on crime and other criteria which differs from the effect the current patrol program would have had if no experiment had been conducted. The difference in the quantitative effects of two alternative patrol programs can never be precisely known, but it is possible to estimate the patrol program impact on crime and arrest rates by the use of the short-term predictive methods mentioned above. Conceptually, a better approach would be to compare the two patrol programs in two identical districts—that is, in a control district that is identical to the experimental district. The difficulty that arises is that no two districts are truly identical in all respects. Thus, it is necessary to ask, for example, which demographic, socioeconomic and criminal justice system characteristics explain the observed variation in reported crime among neighborhoods, so that adjustments may be made for the variation in crime across neighborhoods attributable to factors other than preventive patrol variations. In Chapter III some alternative models of crime were explored using citywide values of crime, police, and demographic measures. We concluded there that such models should be explored further, but where feasible using time-series data and/or data disaggregated by small geographic area.

During the period of experimentation, changes other than police activities also may take place that would affect the crime rate. These changes might be social or economic in nature, or might be attributable to other characteristics of the criminal justice system. A model of the determinants of crime would also be useful to adjust for variation in crime within a given geographical area over time. Knowledge of the determinants of crime also would have broader uses, for example, in evaluating alternative social programs that impinge on crime, including those of other criminal justice agencies.

Methods for Allocation of Patrol Forces

As indicated in the President's Commission Task Force Report[5] of the 1967 President's Commission on Law Enforcement and the Administration of Justice:

> Many American police forces do not utilize their available field personnel effectively. The most significant weakness appears to be the failure of departments to distribute patrol officers in accordance with the actual need for their presence.

In Chapter IV we outlined what we believe to be the best currently feasible approach to aid in allocating patrol forces in response to the constantly changing patterns of need for police services. It involves prediction of crime and call-for-service workload, using multiple criteria with each measure treated separately, analytic models relating patrol inputs to the criteria, and a mathematical programming technique that will estimate the patrol program which best satisfies the criteria specified. For evaluation of specific and complex alternative patrol tactics or command-control systems, the system could be simulated.

The approach we suggest for aiding in deploying patrol by neighborhood and time periods is theoretically feasible and logically seems to have significant advantages over any deployment method that is currently operational. Further research and experimentation is needed to test, refine, and implement this method in actual patrol operation.

[5] *Task Force Report: The Police,* p. 51.

Appendix

A PRELIMINARY STATISTICAL ANALYSIS OF POLICE STRENGTH, CRIME, AND DEMOGRAPHIC FACTORS

All police departments have the problems of determining the overall force level, the patrol manpower level required, and effective allocation of patrol forces to each shift and division. Estimating the effectiveness of police in influencing crime rate, in responding to calls for service and in apprehending suspected criminals, is central in addressing these problems. Moreover, the number of assigned officers or patrol cars is probably only one of the many factors influencing crime rate. For example, changing population characteristics within a city, or differences in population characteristics among cities, might explain some of the differences in crime rate. Such demographic factors as population density, proportion of the population in particular age groups, median income level, educational attainment, and mobility are prime variables to be explored.

As we indicated in Chapter V, the final determination of the effect of police manning level on crime must come from controlled experiments in the field. But the experiments should be preceded by preliminary statistical analysis so that the experiments can be more productive of both information and crime reduction. These statistical analyses can be performed on citywide data using data from a set of cities for a given year. Such analyses are relevant to the issue of determining adequate patrol force level. When similar analyses are performed on precinct or division data from a single city, the analyses are relevant to the allocation of patrol resources to divisions. In this appendix we address the force level question, using data from several cities for a single year.

An inherent difficulty of most statistical analysis is its inability to distinguish between cause and effect. Because rising crime rate may result in additional police manpower allocations, the two may appear positively correlated. But this does not mean that additional police *cause* additional crime.

Three data sets were employed in the statistical analysis: the six-city sample and 30-city subsets,[1] of the 37 cities comprising the Kansas City Police Department annual survey of municipal police departments.

ANALYSIS OF THE SIX-CITY SAMPLE

A regression analysis of some of the variables in the six-city sample revealed statistically significant relationships between several pairs of variables.[2] Figures A-1 through A-4 display the data points together with the fitted relationships. Note that for Cities "X" and "Y" absolute values of calls for service, population, and patrol strength are not shown on the figure, but they have been employed in fitting the relationships. However, the per capita and per square mile data for these cities are shown on Figs. A-3 and A-4, if available.[3]

The relationships shown in Figs. A-1 through A-4 are intuitively reasonable. Larger cities should generate more calls for service (Fig. A-1), and more calls for service should contribute to decisions to increase police budgets and, hence, patrol strength (Fig. A-2). Such relationships are not unexpected, because they essentially stem from the size factor. More interestingly, higher densities of calls for service seem to be associated with higher patrol density (Fig. A-3); however, linear relationships should not be inferred because of the small sample, and because patrol densities are very low in two of the five departments. Phoenix, and especially Los Angeles County, have large areas of low population density which are very thinly patrolled.

The data in Fig. A-4 indicate that there may be a weak positive association between total uniformed patrol strength per thousand population and the chances of being a victim of a serious crime (i.e., a Part I crime). Overall uniformed patrol strength per capita is higher in cities with higher victimization rate. However, little can be concluded from using such a small sample, especially since two cities, Los Angeles and City "Y," show large deviations. At best, these relationships are indicative of those which should be explored using larger samples of cities. We have used the six-city statistical analysis as a starting point for analyzing the 30-city sample data sets. Unfortunately, the 30-city data sets contain no information on call-for-service volume; therefore, numbers of reported serious crimes and victimization rates are the only available measures of demand or output.

ANALYSIS OF THE 1968 30-CITY SAMPLE

Table A-1 displays selected police input data from the 1968 Kansas City

[1] Seven of the 37 cities were omitted because they employed a significant proportion of the patrol force on foot. In our analysis, one of the relevant measures of police presence tested was patrol cars on the street per shift. If a significant fraction of the patrol force is on foot in a given city, this would introduce bias if that city were included in the sample.

[2] There may be significant correlations between other variable pairs, but limited resources did not permit us to test all of the interesting combinations. Also, pairwise regression is only of limited value because it ignores probable effects of excluded variables.

[3] Calls for service are not available for City "X," as indicated in Table 3 of the main body of the report.

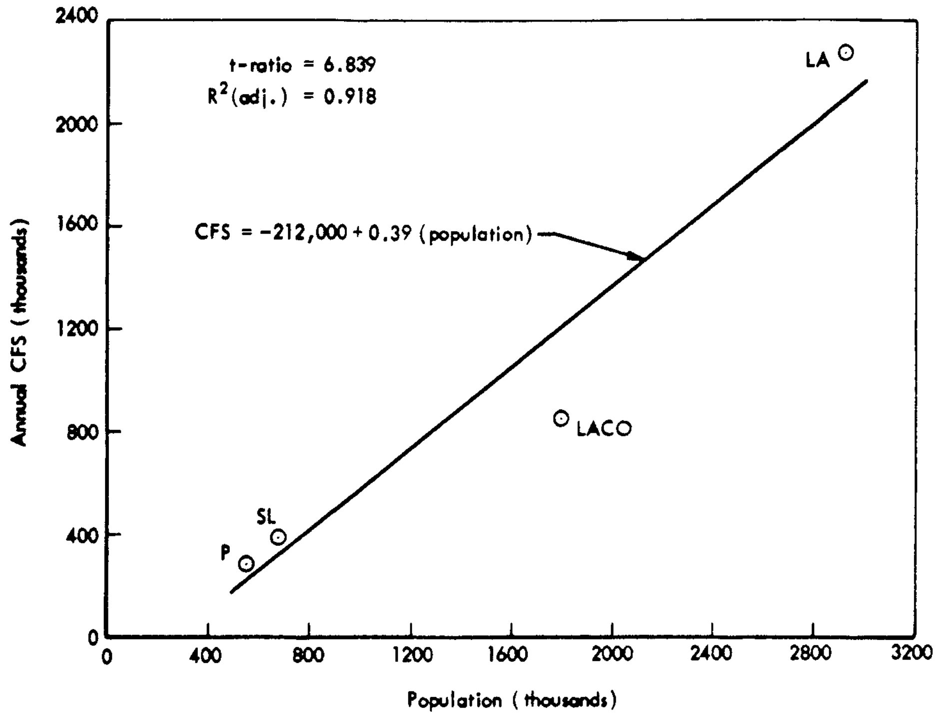

Fig. A-1—Annual calls for service (CFS) versus population

Police Department Survey, selected crime measures from the 1968 FBI Uniform Crime Reports (UCR), and population, area, and population density for the 30 cities.

Simple pairwise correlation of variables aided our intuition in postulating models. Table A-2 displays the correlation coefficient matrix. As one would expect, statistically significant relationships exist between the crime measures themselves, between the police input measures themselves, and between the crime and police input measures; this is true for measures expressed in absolute or per capita terms.[4] However, the crime and police input measures are *positively* related, so that cities with more reported crime or crime per capita have more police and patrol cars in absolute and per capita terms. Population is also positively associated with all crime and police input measures. Area is unrelated to absolute measures of crime and police inputs but generally is negatively associated with these measures, when stated in per capita terms. Population density is positively associated with all measures of crime and police inputs.

[4] For 30 observations (cities), a reasonable rule of thumb to use in judging whether or not the relationship between two variables is statistically significant is whether the absolute value of the correlation coefficient exceeds .25 or .30.

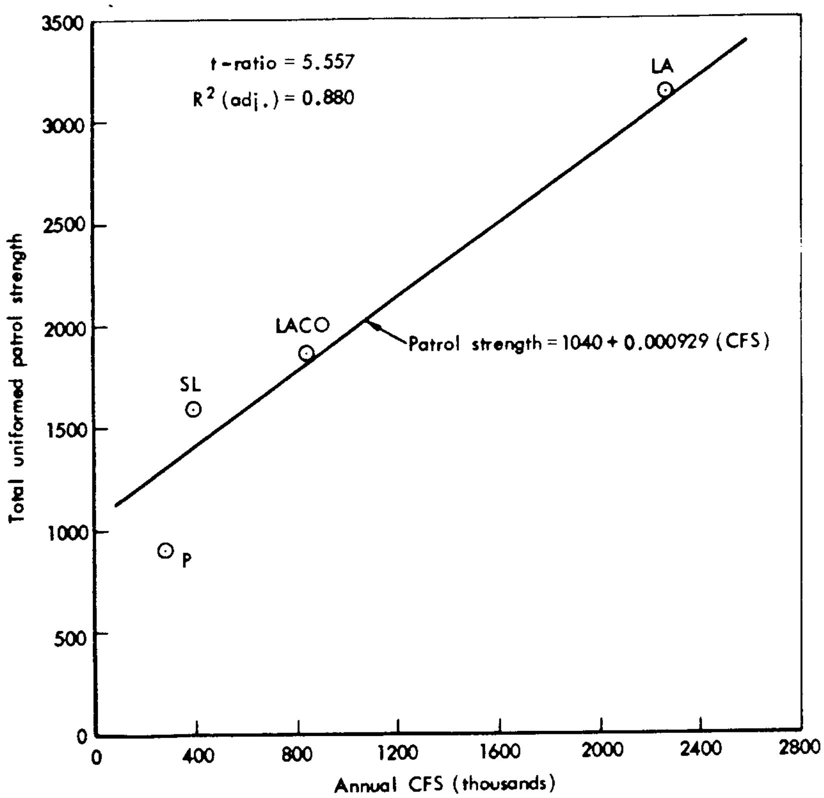

Fig. A-2—Total uniformed patrol strength versus annual CFS

We postulated a series of models and relationships and then used two multivariate regression techniques to test the "explanatory powers" of the models.

First, using ordinary least-squares estimation, we postulated several models —one set using absolute values for the variables and a second set with relative values (i.e., on a per capita or per square mile basis).

For the "absolute value" set, we show below the fitted regression equation. Above each independent variable we display the t-ratio value—values above 2.0 are enclosed in a box;[5] R^2, the coefficient of determination, is shown at the right of each equation.[6]

[5] A reasonable rule of thumb for these and the following regression analyses is that the relationship is statistically significant for values of the t-ratio > 2. That is, the coefficient of the variable is statistically significant.

[6] The coefficient of determination, R^2, shows the percent of the variance of the dependent variable explained by the particular regression model.

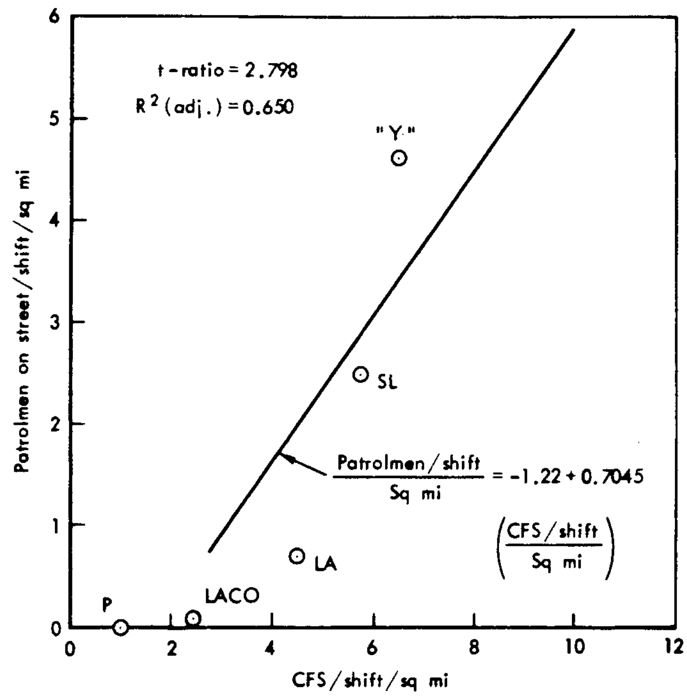

Fig. A-3—Density of patrol versus density of CFS (per average shift)

$$\text{(1)}\quad \text{Index crimes} = 4000 + \underset{(t = \boxed{9.065})}{18.06\,[\text{police}]} \quad (R^2 = .75)$$

$$\text{(2)}\quad \text{Index crimes} = -2076 + \underset{(t = \boxed{5.119})}{13.13\,[\text{police}]} + \underset{(t = \boxed{2.693})}{19.96\left[\frac{\text{population}}{1000}\right]} \quad (R^2 = .80)$$

$$\text{(3)}\quad \text{Index crimes} = -1971 + \underset{(t = \boxed{3.340})}{13.22\,[\text{police}]} + \underset{(t = \boxed{2.026})}{19.77\left[\frac{\text{population}}{1000}\right]} - \underset{(t = -.0294)}{0.17\,[\text{population density}]} \quad (R^2 = .80)$$

Table A-1

MEASURES OF CRIME AND POLICE INPUTS IN 30 CITIES--1968

City Number	City	Population	Population Density (pop/sq mi)	Police Budget per Capita ($)	Police Officers per 1000 Pop.	Patrol Cars per Shift	Patrol Cars per Shift per 1000 Pop.	Robberies	Index Crimes	Robberies per 1000 Population	Index Crimes per Capita (victimization rate)
1	Baltimore	914,600	9,750	53.26	3.42	176	.192	8683	67,157	9.49	.0734
2	Birmingham	353,000	4,640	12.89	1.43	27	.076	403	11,557	1.14	.0327
3	Buffalo	481,400	9,590	32.40	2.80	38	.079	1090	15,891	2.26	.0330
4	Cincinnati	502,600	6,480	19.32	1.82	64	.127	801	11,609	1.59	.0231
5	Cleveland	810,800	10,720	25.09	2.68	86	.106	3531	34,028	4.35	.0420
6	Columbus	581,900	5,010	13.69	1.36	54	.093	1171	19,721	2.01	.0339
7	Dallas	859,900	2,910	15.96	1.74	94	.109	1100	24,170	1.27	.0281
8	Denver	535,000	5,470	14.49	1.59	40	.075	1401	24,072	2.61	.0450
9	Fort Worth	417,000	2,120	13.02	1.33	45	.108	538	11,646	1.29	.0279
10	Houston	1,230,000	2,720	14.44	1.21	58	.047	4155	47,955	3.37	.0390
11	Indianapolis	530,000	6,160	17.59	1.82	48	.091	1880	20,687	3.54	.0390
12	Kansas City	585,400	1,850	18.49	1.58	54	.092	2171	25,282	3.70	.0432
13	Long Beach	391,000	8,180	21.61	1.66	19	.048	999	14,669	2.55	.0375
14	Louisville	392,100	6,040	15.95	1.49	32	.082	1163	17,940	2.96	.0458
15	Memphis	650,000	3,940	17.30	1.40	34	.052	991	17,783	1.52	.0274
16	New Orleans	673,000	1,850	21.40	1.99	62	.092	2194	26,607	3.26	.0395
17	Norfolk	322,000	5,210	14.46	1.52	25	.078	655	11,736	2.03	.0364
18	Oakland	400,000	5,060	31.17	1.63	27	.067	2753	28,333	6.88	.0708
19	Oklahoma City	405,000	620	9.22	1.11	26	.064	482	10,138	1.19	.0250
20	Omaha	380,000	5,510	11.86	1.22	35	.092	658	10,523	1.73	.0277
21	Phoenix	527,800	2,130	20.37	1.46	63	.119	938	22.217	1.77	.0421
22	Pittsburgh	548,400	9,520	25.23	2.86	39	.071	2972	32,230	5.41	.0588
23	Portland	385,800	4,430	22.39	1.87	27	.070	1122	17,044	2.90	.0442
24	Rochester	300,000	8,190	20.57	1.96	32	.107	540	9,789	1.80	.0326
25	St. Louis	699,000	11,380	33.75	2.91	109	.156	4180	39,054	5.97	.0559
26	St. Paul	317,000	5,870	14.61	1.43	23	.073	901	15,300	2.84	.0483
27	San Antonio	726,700	3,980	11.45	1.01	58	.080	784	26,903	1.07	.0370
28	San Diego	681,300	1,790	19.11	1.30	63	.092	592	16,320	0.86	.0239
29	Seattle	580,000	6,330	19.18	1.81	36	.062	2297	25,247	3.96	.0435
30	Toledo	395,000	4,590	15.82	1.83	24	.061	1027	9,372	2.60	.0237

Table A-2

CORRELATION MATRIX--1968*

Items Compared	Population	Area	Police	Patrol Cars on Street per Shift	Index Crimes	Robberies	Population Density	Police per 1000 Pop.	Patrol Cars on Street per Shift per 1000 Pop.	Index Crimes per Capita	Robberies per 1000 Population
Population	1.000	.3995	.7123	.6785	.7780	.6231	-.0086	.2202	.2482	.1647	.3006
Area	.3995	1.000	-.0342	.0779	.0707	-.0488	-.7306	-.3941	-.1326	-.3043	-.2628
Police	.7123	-.0342	1.000	.8724	.8636	.8853	.5208	.8144	.6183	.5037	.7082
Patrol Cars on Street per Shift	.6785	.0779	.8724	1.000	.7850	.7765	.2871	.5841	.8498	.3847	.5476
Index Crimes	.7780	.0707	.8636	.7850	1.000	.9468	.3226	.5583	.4660	.7111	.7913
Robberies	.6231	-.0488	.8853	.7765	.4468	1.000	.4498	.6904	.5348	.7333	.8975
Population Density	-.0086	-.7306	.5208	.2871	.3226	.4498	1.000	.7799	.3387	.4506	.5402
Police per 1000 Pop.	.2202	-.3941	.8144	.5841	.5583	.6904	.7799	1.000	.5546	.5426	.7156
Patrol Cars on Street per Shift per 1000 Pop.	.2482	-.1326	.6183	.8498	.4660	.5348	.3387	.5546	1.000	.3053	.4207
Index Crimes per Capita	.1647	-.3043	.5037	.3847	.7111	.7333	.4506	.5426	.3053	1.000	.8986
Robberies per 1000 Population	.3006	-.2628	.7082	.5476	.7913	.8975	.5402	.7156	.4207	.8986	1.000

*A matrix element is the simple correlation coefficient between the column and row factors.

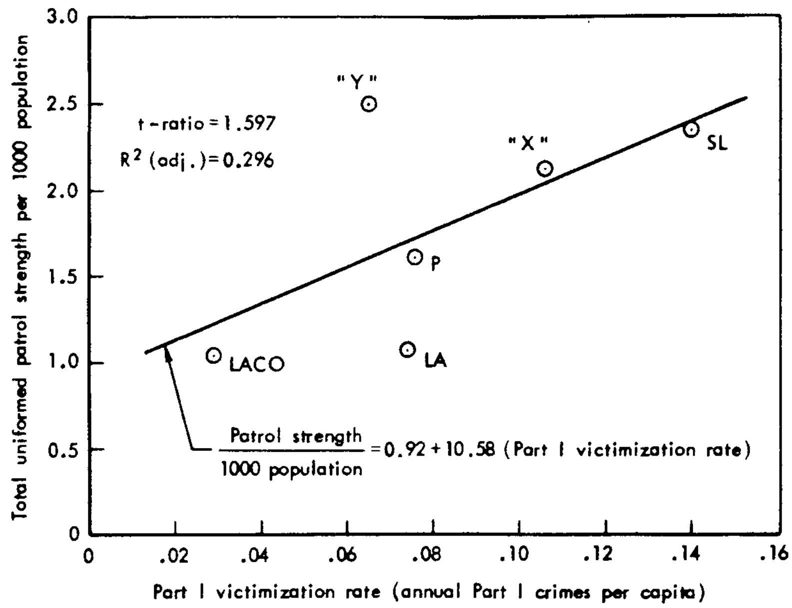

Fig. A-4—Uniformed patrol strength per 1000 population versus victimization rate (Part I crimes)

$$(4)\quad \text{Police} = 90.58 + \underset{(t\,=\,\boxed{9.065})}{.0413\,[\text{Index crimes}]} \quad (R^2 = .75)$$

$$(5)\quad \text{Police} = 11.62 + \underset{(t\,=\,\boxed{5.119})}{.0375\,[\text{Index crimes}]} + \underset{(t\,=\,.6687)}{.2958\left[\frac{\text{population}}{1000}\right]} \quad (R^2 = .75)$$

$$(6)\quad \text{Police} = -7.374 + \underset{(t\,=\,\boxed{4.106})}{.0320\,[\text{Index crimes}]} + \underset{(t\,=\,1.502)}{.770\left[\frac{\text{population}}{1000}\right]} - \underset{(t\,=\,1.683)}{.773\,[\text{area}]} \quad (R^2 = .77)$$

These models reveal that Index crimes and police strength are *positively* and significantly associated; that, considering the three models tested, Index crimes can best be predicted by Model (2) as a function of police strength and population (i.e., adding population density did not improve the estimate); and that, considering the three models tested, police strength can best be predicted by Model (4) as a function only of Index crimes (i.e., adding population, or area for that matter, did not significantly improve the estimate). One cannot conclude, of course, that an increase in police strength creates more Index crimes, or vice versa. Our hypothesis was that, *ceteris paribus,* more police should deter and prevent crime, i.e., that the two factors are negatively related. But this effect, if present, is extremely difficult to discern in aggregated cross-sectional data (i.e., data at one point in time for various cities). It is our belief that disaggregated time-series data for one city (or several cities) should be analyzed to test this hypothesis.

It is interesting to note that a yardstick for police strength has been proposed in Great Britain using similar multiple regression techniques. Using 1964 data for 29 police forces, the following regression equation resulted:

$$\text{Police strength (male establishment)} = \frac{\text{population}}{1000} + \frac{\text{acreage}}{350} + \frac{\text{mileage}}{2.9} + \frac{\text{crime}}{40}.$$

Police strength estimates produced by this formula agree within 2.5 percent of the observed figures for all but one or two smaller police forces.[7]

Thus, the British model for predicting police strength is different from the one that emerges from the analysis of 30 U.S. cities (Model 4). Moreover, the British model seems to be more accurate, since their basic data exhibit less variation than do the U.S. data. We cannot speculate on the reasons for these disparities other than to raise the question regarding the uniformity of crime reporting practices and procedures within the two countries.

Using ordinary least-squares estimation, and weighting the variables by population, similar models (on a per capita basis) were also tested.[8] The following were obtained.

$$(7) \quad \frac{\text{Index crime}}{1000\ \text{pop.}} = 18.63 + \underset{(t\ =\ \boxed{3.418})}{11.68} \left[\frac{\text{police}}{1000\ \text{pop.}}\right] \quad (R^2 = .29)$$

[7] R. Catstree, T. J. Kempton, *Assessment of Police Establishments by Formula—Proposed Yardstick for City and Borough Forces,* Report No. 3/67, Police Research and Development Branch, Home Office, London.

[8] Weighting by population corrects for a phenomenon known as heteroscedasticity (i.e., where the expected value of the variance in the error term varies across observations).

$$(8)\quad \frac{\text{Index crime}}{\text{1000 pop.}} = 17.12 + \underset{(t = \boxed{2.403})}{12.16}\left[\frac{\text{police}}{\text{1000 pop.}}\right] + \underset{(t = .1418)}{.00054}\left[\begin{matrix}\text{population}\\ \text{density}\end{matrix}\right] \quad (R^2 = .41)$$

$$(9)\quad \frac{\text{Police}}{\text{1000 pop.}} = .7825 + \underset{(t = \boxed{3.418})}{.0252}\left[\frac{\text{Index crime}}{\text{1000 pop.}}\right] \quad (R^2 = .29)$$

$$(10)\quad \frac{\text{Police}}{\text{1000 pop.}} = .482 + \underset{(t = \boxed{2.403})}{.0145}\left[\frac{\text{Index crime}}{\text{1000 pop.}}\right] + \underset{(t = \boxed{5.447})}{.000141}\left[\begin{matrix}\text{population}\\ \text{density}\end{matrix}\right] \quad (R^2 = .72)$$

Note that expressing the variables on a per capita basis results in much greater variability in the data and less of the variance in the dependent variables being explained by the models. We note that crime per capita can be predicted more accurately ($R^2 = .41$) using police per capita and population density (Model 8), even though population density is not statistically significant; Model (7), which does not use population density, explains only 29 percent of the variance in crime per capita.

Model (9) predicts police per capita in terms only of crime per capita. Note that this is the same model that was employed in our six-city sample (see Fig. 8), and that the values of R^2 of both the six- and 30-city sample were roughly the same (.29 and .30). But adding population density (Model 10) improves the estimate considerably; R^2 is increased to .72 and both crime per capita and population have significant t-ratio values.

We also employed simultaneous estimation techniques, in particular a two-stage, least-squares multivariate regression analysis.[9] The basis for applying such a technique was the notion that the relationship between measures of crime and police inputs is more complex and interactive; in particular, we postulated that crime is related to population and police strength, and police strength, in turn, is affected by crime and police budget. These are shown in Model (11) below.

[9] The particular algorithm employed is described in Phoebus J. Dhrymes, *Econometrics: Statistical Foundations and Applications*, Harper and Row, 1970 (pp. 183-190). The computer program, known as Regression Analysis Package for Economists, was prepared by William J. Raduchel of the Harvard Institute of Economic Research. The description of the computer program will be published shortly.

$$
(11)\quad \begin{cases}
\text{Index crime} = -1600 + \overset{(t\,=\,\boxed{6.870})}{16.78\,[\text{police}]} \\
\qquad\qquad + \overset{(t\,=\,1.855)}{6878\left[\dfrac{\text{population}}{1000}\right]} \\
\text{Police} = 75.96 + \overset{(t\,=\,\boxed{2.117})}{.0238\,[\text{Index crime}]} + \overset{(t\,=\,\boxed{2.298})}{.0353\,[\text{budget}]}
\end{cases}
$$

This is a much more satisfactory model, since it is intuitively more appealing and it largely succeeds in explaining the variance in the dependent (i.e., endogenous) variables.

A similar model was postulated, but one in which the crime variable was robbery (a crime which might be suppressible by patrol) and the police variable was patrol cars on the street per shift, a measure of police presence in the field. These variables replaced Index crime and police in Model (11). However, this model was less successful than Model (11), and we suspect that this is partially due to the high variance in robbery rate.

In applying two stage, least-squares regression analysis to models similar to Model (11), but where the variables are expressed in *per capita* terms, we noted no significant results. This held whether the endogenous variable pairs were Index crime per capita and police per capita or robbery per capita and patrol cars on the street per shift per capita.

ANALYSIS OF THE 1960 30-CITY SAMPLE

Table A-3 displays, for the same 30 cities, selected police input data from the 1960 Kansas City Survey and selected crime measures from the 1960 UCR. Table A-4 shows the four demographic variables noted above, as drawn from the 1960 Census.

Table A-5 displays the correlation coefficient matrix. We see that among the demographic variables themselves, the following pairs are significantly and positively associated: percentages of nonwhite and poor; percentages of poor and young people; and the mobility factor and percentages of young people. These results are certainly not counterintuitive. Population density and the mobility factor are negatively and significantly related. Apparently, for this 30-city sample, cities with lower population density tended to have a greater proportion of mobile residents in 1960.

Larger cities were more densely populated and had a greater proportion of nonwhites, more police, and more crime. Consistent with 1968 data, cities with more crime had more police. Police and crime are positively related to percentage of

Table A-3

MEASURES OF CRIME AND POLICE INPUTS IN 30 CITIES--1960

City Number	City	Population	Area (sq mi)	Police Budget ($ thousands)	Police Budget per Capita ($)	Police Officers	Police per 1000 Pop.	Index Crimes	Robberies	Index Crimes per 1000 Pop.
1	Baltimore	939,000	93.81	48,715	51.88	3127	3.33	15,290	880	16.28
2	Birmingham	340,900	76.00	4,551	13.35	505	1.48	6,264	216	18.37
3	Buffalo	532,800	50.20	15,600	29.28	1348	2.53	5,383	165	10.10
4	Cincinnati	502,600	77.60	9,710	19.32	915	1.82	4,375	228	8.70
5	Cleveland	876,100	75.66	20,238	23.22	2173	2.48	9,242	1303	10.55
6	Columbus	471,300	116.10	7,965	16.90	792	1.68	7,815	507	16.58
7	Dallas	679,700	295.28	13,723	20.19	1496	2.20	10,383	545	15.28
8	Denver	493,900	97.80	7,754	15.70	854	1.73	11,521	1034	23.33
9	Fort Worth	356,300	196.30	5,430	15.24	556	1.56	6,198	301	17.40
10	Houston	938,200	452.00	17,760	18.93	1482	1.58	18,371	614	19.58
11	Indianapolis	476,300	86.00	9,326	19.58	962	2.02	7,026	472	14.75
12	Kansas City	475,500	316.83	10,822	22.76	927	1.95	13,152	1969	27.66
13	Long Beach	344,200	47.81	8,450	24.55	651	1.89	8,962	568	26.04
14	Louisville	390,600	64.89	6,254	16.01	586	1.50	8,391	562	21.48
15	Memphis	497,500	165.00	11,244	22.60	905	1.82	6,611	274	13.29
16	New Orleans	627,500	364.50	14,401	22.95	1337	2.13	13,514	947	21.54
17	Norfolk	304,900	61.85	4,659	15.28	491	1.61	4,176	122	13.70
18	Oakland	367,500	79.10	12,466	33.92	650	1.77	7,233	539	19.68
19	Oklahoma City	324,300	649.75	3,733	11.51	448	1.38	5,950	289	18.35
20	Omaha	301,600	69.00	4,506	14.94	464	1.54	2,832	161	9.39
21	Phoenix	439,200	247.60	10,752	24.48	773	1.76	9,982	403	22.73
22	Pittsburgh	604,300	57.63	13,832	22.89	1565	2.59	12,932	792	21.40
23	Portland	372,700	87.00	8,639	23.18	719	1.93	6,791	349	18.22
24	Rochester	318,600	36.60	6,171	19.37	589	1.85	2,709	83	8.50
25	St. Louis	750,000	61.40	23,595	31.46	2033	2.71	23,363	2157	31.15
26	St. Paul	313,400	54.00	4,632	14.78	451	1.44	4,593	253	14.66
27	San Antonio	587,700	182.57	8,322	14.16	735	1.25	11,056	241	18.81
28	San Diego	573,200	379.90	13,017	22.71	888	1.55	7,866	336	13.72
29	Seattle	557,100	91.57	11,125	19.97	1047	1.88	9,936	500	17.84
30	Toledo	318,000	86.00	6,249	19.65	722	2.27	4,710	319	14.81

Table A-4

SOME DEMOGRAPHIC FACTORS--1960 CENSUS

City Number	City	Percent Nonwhite	Percent Poor (income under $3000)	Percent Young (age 15-29)	Mobility (percent moved into house after 1958)
1	Baltimore	35.0	14.5	31.9	22.5
2	Birmingham	39.7	25.5	36.5	24.7
3	Buffalo	13.8	17.3	18.8	21.7
4	Cincinnati	21.8	19.6	40.0	28.1
5	Cleveland	28.9	17.2	36.5	26.4
6	Columbus	16.6	16.1	28.9	34.8
7	Dallas	19.3	18.4	33.1	33.3
8	Denver	7.1	15.1	32.5	30.9
9	Fort Worth	16.0	21.3	32.9	32.1
10	Houston	23.2	18.8	26.8	30.8
11	Indianapolis	20.7	15.6	27.8	28.8
12	Kansas City	17.7	17.6	40.4	28.4
13	Long Beach	4.3	16.6	21.3	65.7
14	Louisville	18.0	21.8	13.2	27.4
15	Memphis	37.1	27.0	19.9	29.4
16	New Orleans	37.4	27.8	26.5	25.0
17	Norfolk	26.4	29.4	47.4	37.6
18	Oakland	26.4	17.3	17.7	29.2
19	Oklahoma City	13.0	19.2	33.7	31.7
20	Omaha	8.7	13.2	11.4	26.9
21	Phoenix	5.8	16.8	30.6	35.4
22	Pittsburgh	16.8	18.4	18.7	19.0
23	Portland	5.6	15.1	16.6	25.9
24	Rochester	7.6	14.2	19.1	23.6
25	St. Louis	28.8	21.7	49.6	27.8
26	St. Paul	3.0	11.8	20.2	23.0
27	San Antonio	7.4	27.9	26.5	29.9
28	San Diego	7.8	14.4	45.4	43.7
29	Seattle	8.4	11.8	19.3	27.6
30	Toledo	12.7	15.8	17.5	22.6

nonwhites, but, anomalously, they show no significant relationships with any of the other three demographic variables.

The number of police per capita has a strong positive association with population, police, crime, and percentage of nonwhites, but a strong negative correlation with area; clearly these relations are not counterintuitive. But, it is negatively associated with the mobility factor and percentage of young people; these relationships are counterintuitive.[10]

However, the most disturbing and surprising results occur for the correlation of Index crimes *per capita* with the demographic variables, police, and police per capita. *No significant pairwise correlations exist at all.* Recall that both the 1968 six-city and 30-city samples showed a strong positive relation between crime per

[10] The words *correlation, association,* and *relation* are used interchangeably in the discussion of pairwise correlation.

Table A-5

CORRELATION MATRIX--1960

	Population	Area	Police	Index Crime	Percent Nonwhite	Percent Move	Percent Young	Percent Poor	Population Density	Police per 1000 Pop.	Index Crimes per 1000 Pop.
Population	1.000	.1900	.8928	.7486	.4107	-.0881	-.0078	.0804	.3175	.5798	.1136
Area	.1900	1.000	-.0340	.2266	.0265	.4076	.1962	.1322	-.6795	-.2765	.1771
Police	.8928	-.0340	1.000	.6632	.4390	-.2246	-.1090	.0065	.5472	.8602	.0915
Index crime	.7486	.2266	.6632	1.000	.3000	-.0291	-.1044	.1628	.1900	.4450	.7095
Percent nonwhite	.4107	.0265	.4390	.3000	1.000	-.1630	.0515	.6456	.1309	.3586	.0208
Percent move	-.0881	.4076	-.2246	-.0291	-.1630	1.000	.7638	.0942	-.5332	-.4812	.1049
Percent young	-.0078	.1962	-.1090	-.1044	.0515	.7638	1.000	.2805	-.2121	-.2881	-.1478
Percent poor	.0804	.1322	.0065	.1628	.6456	.0942	.2805	1.000	-.1539	-.0984	.1527
Population density	.3175	-.6795	.5472	.1900	.1309	-.5332	-.2121	-.1539	1.000	.6644	-.0801
Police per 1000 pop.	.5798	-.2765	.8602	.4450	.3586	-.4812	-.2881	-.0984	.6644	1.000	.0698
Index crimes per 1000 population	.1136	.1771	.0915	.7095	.0208	.1049	-.1478	.1527	-.0801	.0698	1.000

capita and police per capita.[11] But for 1960, the correlation coefficient for these two variables is .0698. We cannot account for why this is so except to speculate that crime reporting practices, procedures, and standards may have been much less uniform in 1960 than they are currently.

Given this state of affairs, it is not surprising that several simultaneous estimation models postulated, in which the endogenous variables are *police per capita* and *crime per capita,* fail to reveal significant associations. That is, the two-stage, least-squares regression analysis of 1960 data revealed no significant relationships. Furthermore, all ordinary least-squares analysis which attempts to predict crime per capita as a function of police per capita, or vice versa, and which includes in the model any other variables or combination of variables (such as the demographic factors), failed to result in a significant t-ratio value for police per capita or crime per capita. Thus, it was not possible to discern to what extent demographic variables explain the variation in crime per capita or police per capita.

However, since we indicated that *crime level* and *police strength* were related to each other and to other demographic variables, we would expect to have more success with models using these variables rather than those involving crime and police expressed in per capita terms. Such is the case. Consider the two simple, ordinary least-squares models shown below.

$$\text{(12)}\quad \text{Index crimes} = 3776 + 5.080\underset{(t\,=\,\boxed{4.689})}{[\text{police}]}\quad (R^2 = .44)$$

$$\text{(13)}\quad \text{Police} = 236.7 + .0866\underset{(t\,=\,\boxed{4.689})}{[\text{Index crimes}]}\quad (R^2 = .44)$$

If we now *add* any variable, or variables, to Model (12)—population; population density; percentages poor, young; nonwhite or mobility factor—the police variable is no longer statistically significant. On the other hand, if we completely eliminate the police variable, crime is best predicted by population. And adding demographic variables to the population variable does not improve the estimates materially. This is illustrated below.

$$\text{(14)}\quad \text{Index crimes} = -491.6 + 18.66\underset{(t\,=\,\boxed{5.974})}{\left[\frac{\text{population}}{1000}\right]}\quad (R^2 = .56)$$

$$\text{(15)}\quad \text{Index crimes} = -468.9 + 18.76\underset{(t\,=\,\boxed{5.376})}{\left[\frac{\text{population}}{1000}\right]} - 3.861\underset{(t\,=\,-.0641)}{[\text{percentage nonwhite}]}\quad (R^2 = .56)$$

[11] For the six-city sample we used Part I crimes per capita rather than Index crime per capita.

$$\text{(16)}\quad \text{Index crimes} = -2241 + \overset{(t\,=\,\boxed{5.854})}{18.46\left[\frac{\text{population}}{1000}\right]} + \overset{(t\,=\,.8167)}{98.81\,[\text{percentage poor}]}\qquad (R^2 = .57)$$

Notice that 56 percent of the crime variance is explained by the population model (Model 14) as compared to only 44 percent for the police model (Model 12).

A similar state of affairs holds for the police model. *Adding* any demographic variable to Model (13) results in the police variable no longer being significant. Then, of the simple models tested, police strength is best predicted by population and area. And adding demographic variables improves the R^2 very slightly, but the t-ratio values of these variables are generally not significant. This is illustrated below.

$$\text{(17)}\quad \text{Police} = -383.2 + \overset{(t\,=\,\boxed{11.91})}{3.037\left[\frac{\text{population}}{1000}\right]} - \overset{(t\,=\,\boxed{-2.696})}{.8688\,[\text{area}]}\qquad (R^2 = .84)$$

$$\text{(18)}\quad \text{Police} = -40.98 + \overset{(t\,=\,\boxed{6.286})}{2.565\left[\frac{\text{population}}{1000}\right]}$$

$$- \overset{(t\,=\,\boxed{-2.324})}{.7442\,[\text{area}]} + \overset{(t\,=\,.6285)}{.0095\,[\text{Index crime}]}$$

$$\overset{(t\,=\,-1.839)}{-24.22\,[\text{percentage poor}]} + \overset{(t\,=\,\boxed{2.163})}{13.79\,[\text{nonwhite}]}\qquad (R^2 = .87)$$

$$\text{(19)}\quad \text{Police} = -415.4 + \overset{(t\,=\,\boxed{7.074})}{2.828\left[\frac{\text{population}}{1000}\right]}$$

$$- \overset{(t\,=\,\boxed{-2.607})}{.8575\,[\text{area}]} + \overset{(t\,=\,.2541)}{.0039\,[\text{Index crime}]}$$

$$+ \overset{(t\,=\,1.176)}{5.644\,[\text{percentage nonwhite}]}\qquad (R^2 = .85)$$

Notice that the pure population and area model explains 84 percent of the police strength variance (Model 17), whereas crime explains only 44 percent of the variance (Model 13). Adding crime, percentage poor, percentage nonwhite, or a combination of nonwhite and crime increases the explanatory power of the model only slightly (Models 18 and 19).

A summary and assessment of such analysis is contained in Chapter III.