HOW TO SET UP SHOP FOR USE OF THE HYPERCUBE SYSTEM

THE INSTITUTE FOR PUBLIC PROGRAM ANALYSIS

[illegible]30 S. BEMISTON SUITE 914
ST. LOUIS, MISSOURI 63105

Allen D. Gill
Richard A. Kolde
William W. Stenzel D.Sc.
Nelson B. Heller Ph.D.

October 1977

(01) PB-277 024 u7808
U053104

(04) PC$4.50/MF$3.00; (F):PC$9.00/MF$4.50
(05) Institute for Public Program Analysis, St. Louis, Mo.*National Science Foundation, Washington, D.C. Applied Science Research Applications.
(06) Field Evaluation of the Hypercube System for the Analysis of Police Patrol Operations: Executive Summary,
(10) N. B. Heller; W. W. Stenzel; A. D. Gill
(11) Oct 77, (12) 31p
(15)(GR) NSF-APR75-17472
(18) NSF/RA-770400
(21) See also PB-277 025.(PC A03/MF A01)

(01) PB-277 025 u7808
U053106

(04) PC$6.00/MF$3.00; (F):PC$12.00/MF$4.50
(05) Institute for Public Program Analysis, St. Louis, Mo.*National Science Foundation, Washington, D.C. Applied Science Research Applications.
(06) How to Set Up Shop for Use of the Hypercube System,
(10) A. D. Gill; R. A. Kolde;] W. W. Stenzel; N. B. Heller] (11) Oct 77, (12) 93p
(15)(GR) NSF-APR75-17472
(18) NSF/RA-770401
(21) See also PB-277 026.(PC A05/MF A01)

u7808
U053099
(01) PB-277 026

(04) PC$10.75/MF$3.00; (F):PC$21.50/MF$4.50
(05) Institute for Public Program Analysis, St. Louis, Mo.*National Science Foundation, Washington, D.C. Research Applied to National Needs.
(06) Field Evaluation of the Hypercube System for the Analysis of Police Patrol Operatins.
(09) Final rept.,
(10) Nelson B. Heller;] William W. Stenzel;] Allen D. Gill; Richard A. Kolde (11) Oct 77,
(12) 264p
(15)(GR) NSF-APR75-17472
(18) NSF/RA-770403
(21) See also PB-277 024.(PC A12/MF A01)

THE INSTITUTE FOR PUBLIC PROGRAM ANALYSIS

HOW TO SET UP SHOP FOR USE OF THE HYPERCUBE SYSTEM

230 S. BEMISTON SUITE 914 • ST. LOUIS, MISSOURI 63105

EXECUTIVE DIRECTOR
Nelson B. Heller, Ph.D.

ASSOCIATE DIRECTOR
William W. Stenzel, D.Sc.

Allen D. Gill
Richard A. Kolde
William W. Stenzel, D.Sc.
Nelson B. Heller, Ph.D.

October, 1977

Prepared under NSF Grant APR75-17472, "Field Evaluation of the NSF-MIT Hypercube Patrol Sector Design Methods," National Science Foundation, Research Applied to National Needs, Division of Advanced Productivity Research and Technology.

ABSTRACT

This report is one product of the project "Field Evaluation of the NSF-MIT Hypercube Patrol Sector Design Methods," funded by the National Science Foundation, Grant Number APR75-17472. The hypercube system is a computerized planning tool used to evaluate alternative police beat structures and patrol deployment policies. The study was conducted by The Institute for Public Program Analysis in cooperation with the California Innovation Group (an NSF-funded consortium of cities active in technology transfer) and police departments in St. Louis County, Missouri, and the California cities of Burbank, Fresno, Garden Grove, Huntington Beach, Pasadena, San Diego, San Jose, Santa Ana, and Santa Clara.

The information contained in the report is based upon the latest hypercube documentation and the experiences of the 10 police departments which participated in the field evaluation project. Designed for police agencies considering the use of hypercube, the report is intended to give a concise overview of the procedures and issues involved in hypercube use. Topics covered include: an overview of the capabilities and limitations of the hypercube system; its benefits; the computer hardware and data processing services needed; the software options available; the costs of using the system; the kinds of data needed; and sources of hypercube materials, training and technical assistance. In addition, background information is presented on other patrol allocation and beat design methods and the process of implementing revised beat plans.

PREFACE

This report is one product of the project "Field Evaluation of the NSF-MIT Hypercube Patrol Sector Design Methods." This project was funded by the National Science Foundation (Grant Number APR75-17472) through its program of Research Applied to National Needs (RANN), Division of Advanced Productivity Research and Technology. The study was conducted by The Institute for Public Program Analysis, a non-profit research firm located in St. Louis, Missouri, in cooperation with the California Innovation Group (an NSF-funded consortium of cities active in technology transfer) and police departments in St. Louis County, Missouri, and the California cities of Burbank, Fresno, Garden Grove, Huntington Beach, Pasadena, San Diego, San Jose, Santa Ana, and Santa Clara.

Other products of the study include the following reports:

- Field Evaluation of the Hypercube System for the Analysis of Police Patrol Operations: Executive Summary - a brief, non-technical summary of the project;

- Instructional Materials for Learning to Use the Hypercube Programs for Analysis of Police Patrol Operations - a handbook describing the use of hypercube computer programs for the design and analysis of police patrol operations; and

- Field Evaluation of the Hypercube System for the Analysis of Police Patrol Operations: Final Report - a description of the objectives, methods, and findings of the field test project, including brief case studies of the experiences of participating police departments, a preliminary assessment of the accuracy of hypercube field performance estimates, costs of using the hypercube system, technical assistance required for hypercube users, and dissemination and utilization of the hypercube system.

These documents are available from The Institute for Public Program Analysis and from the National Technical Information Service (NTIS), Springfield, Virginia.*

In addition to the staffs of the California Innovation Group and the participating police departments cited above, the authors gratefully acknowledge the cooperation, assistance, and support of Ms. Lynn Preston, Dr. David Seidman, and Dr. Neil Dumas, who served as NSF's program managers at various times during the project. The authors also gratefully acknowledge

---

*Appendix B lists the addresses for the various suppliers of hypercube materials, training, and technical assistance.

the assistance of the members of the project's advisory board:

- Mr. Norman Darwick, Director, Police Management and Operations Division, International Association of Chiefs of Police;
- Mr. Del DelaBarre, Executive Director, California Innovation Group;
- Dr. George Kelling, Police Foundation;
- Col. Gilbert Kleinknecht, Superintendent, St. Louis County Police Department;
- Mr. Robert Kleismet, Vice President, International Conference of Police Associations;
- Dr. Michael Maltz, Department of Criminal Justice, University of Illinois at Chicago Circle; and
- Mr. Richard Valdez, Bureau of Planning and Research, St. Louis County Police Department.

The authors have corresponded with many other persons and organizations. They have assisted the project in a variety of ways, and their contributions are also greatly appreciated.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER I

INTRODUCTION

A. Background

Since their development at the Massachusetts Institute of Technology (M.I.T.), the hypercube programs have attracted considerable attention among law enforcement agencies. Although the programs are suitable for use in analyzing the performance of other urban emergency services, their primary application has been in the field of police patrol deployment. They have been utilized by police departments in New Haven, Connecticut; New York City; Boston, Quincy, and Arlington, Massachusetts; and have been the subject of police planner training workshops at M.I.T., the Northwestern University Traffic Institute, and The Institute for Public Program Analysis.

Briefly stated, the hypercube system is a computerized planning tool which can be used to evaluate alternative beat structures and patrol deployment policies. The system is based upon the hypercube queuing model developed at M.I.T. by Dr. Richard Larson and others. The hypercube computer programs employ information about both the geographic distribution of police called-for-service incidents and field operations policies in order to evaluate patrol beat plans by estimating performance characteristics such as car and beat workloads, the amount of interbeat dispatching, and travel times by car and beat.

B. Purpose of This Document

This document is designed for police agencies considering the use of hypercube and is intended to give an overview of the procedures and issues involved in hypercube use. This document offers information for use in deciding whether hypercube is appropriate for use by a particular department. The topics covered are intended to help answer the basic questions often raised by potential users of the hypercube system:

- What benefits can my department derive from the hypercube system?
- What computer hardware is needed and what software options are available?
- How much will hypercube cost?
- What kinds of data will be needed?
- Where can I obtain additional hypercube materials, training, and technical assistance?

C. Cities Participating in the Project

The information contained in this report is based on the latest hypercube documentation and the experiences of 10 police departments which participated in the project entitled "Field Evaluation of the NSF-MIT Hypercube Patrol Sector Design Methods." The project was coordinated by The Institute for Public Program Analysis. Funding was provided by the Division of Advanced Productivity Research and Technology of the National Science Foundation, which also sponsored the initial development of the hypercube system.

The 10 police departments participating in the project are listed in Table 1-1, along with information on their respective jurisdictions. Nine of these departments are located in jurisdictions covered by the California Innovation Group (CIG). The CIG is an NSF-funded consortium of 10 city-manager cities. The consortium was created to help local governments develop an effective process of technology transfer and to institutionalize this process within the participating cities. A science advisor is assigned to each city manager to provide active leadership and guidance in the promotion of technology utilization. The CIG program is governed by a policy board consisting of the managers and administrative officers from each jurisdiction. Day-to-day management and coordination is provided by the principal CIG investigator, Mr. Del DelaBarre.

During the field test project, police planners in the participating departments were trained in the use of the hypercube system and were given technical assistance in collecting the necessary input data and operating the system. The planners used portable data terminals provided at project expense to access the hypercube programs implemented on the National CSS (NCSS)* time-sharing system.

Two of the 10 participating departments withdrew from the project without performing hypercube analyses of their field operations--one because of the amount of effort that would have been required to collect the input data needed to use the hypercube programs, the other because its patrol beats had recently been realigned and personnel who would have been using hypercube were busy implementing a new team policing program.

Three departments completed patrol deployment analyses and implemented new beat plans designed with hypercube assistance. Burbank's plan included a realignment of the Police Department's two command sectors and the development of a new 10-beat design. In Fresno, new beat plans were developed and implemented for each of four shifts. Hypercube-designed beat plans have been implemented in two of the five St. Louis County precincts.

---

*"CSS," always abbreviated in the corporate title, stands for "Conversational Software System."

Table 1-1

BASIC INFORMATION ON FIELD TEST POLICE AGENCIES

Police Department	Population of Jurisdiction[a]	Size of Jurisdiction (Square Miles)[a]	Number of Beats[b]	Number of Statistical Reporting Areas[b,c]
Burbank	85,000	17.1	14	-
Fresno	175,900	51.0	16	367
Garden Grove	119,600	17.5	6-8	110
Huntington Beach	146,400	25.8	12	127
Pasadena	112,000	22.7	7	150
St. Louis County (Mo.)	350,000	360.0	41-73	476
San Diego	766,100	310.1	96	200
San Jose	547,500	147.4	40	-
Santa Ana	174,800	27.6	8	127
Santa Clara	90,200	18.5	7	50

[a]Based on 1975 estimates supplied by the California Innovation Group and the St. Louis County Police Department.

[b]As of 1975, prior to commencement of field test program.

[c]The cities of Burbank and San Jose did not use statistical reporting areas prior to the field test program. San Jose, however, did devise a system of 280 "Beat Building Blocks" (BBBs) specifically for use during the last beat redesign in 1973.

The remaining five departments experienced varying degrees of progress in their hypercube analyses. Summaries of the experiences of the 10 participating departments are contained in Field Evaluation of the Hypercube System for the Analysis of Police Patrol Operations: Final Report. That document and other sources of hypercube information are described briefly in Chapter IV of this report.

D. Outline and Structure of the Report

The information contained in this chapter is intended as background for detailed discussions of hypercube uses and limitations found in subsequent chapters. The following section of this chapter presents an overview of the criteria used in designing police patrol beats. Beat design is described as one step in the development of a comprehensive patrol allocation plan. Emphasis is placed upon relating beat design to the other aspects of patrol allocation and both manual and computerized methods of designing beats are reviewed.

Chapter II reviews the hypercube system and how it can be used to allocate patrol resources. Topics covered include the basic features of the system, the software options available, and the advantages and disadvantages of using the system. This information is designed to assist potential hypercube users in assessing the potential benefits of hypercube use and determining which of the available versions of the programs is most suitable for their needs.

Chapter III reviews the personnel, data processing, and technical assistance costs associated with using the hypercube system. Emphasis is placed upon enabling prospective users to estimate the costs and feasibility of using the system.

Chapter IV reviews the procedures required for using the hypercube system: obtaining and reviewing hypercube documentation, arranging for data processing services and equipment, obtaining the necessary training and technical assistance, and collecting hypercube input data. The data collection process is described in detail so that prospective users can assess the kinds of data needed and the amount of effort required to obtain the data from department records.

Appendix A contains detailed cost estimation tables mentioned in Chapter III. Appendix B contains the names and addresses of the suppliers of hypercube-related information, materials, training, and technical assistance mentioned in Chapter IV. Appendix C briefly describes the procedures and issues involved in implementing revised beat plans.

E. Overview of Patrol Beat Design

The Police Patrol Function

The most basic police function is that of patrol. Patrol-related activities are the principal means of providing police services, and these activities are the most visible to the public. Patrol activities consume the major portion of police agency resources.

Patrol activities include routine patrol and response to calls for service. Routine patrol, also called preventive patrol or routine surveillance, includes touring an assigned area to make security checks, look for and eliminate crime hazards, intercept crimes in progress, and discourage criminal activity by maintaining a visible police presence in the area. Response to citizen calls includes providing the full range of police services, from taking complaints and reports of crimes, to intervening in disputes and intercepting crimes in progress. Not all of a patrol officer's duty time is spent patrolling and responding to calls; some time is also required for meals, administrative duties, and equipment repair.

Figure 1-1 diagrams the major event sequences in the activities of police patrol units and of the dispatchers who give them their assignments. Another view of the event sequence involved in the arrival and servicing of calls for police service is shown in Figure 1-2. Both figures provide a convenient framework for discussing police patrol operations in general, and for highlighting the features of these operations which can be studied with the hypercube queuing model.

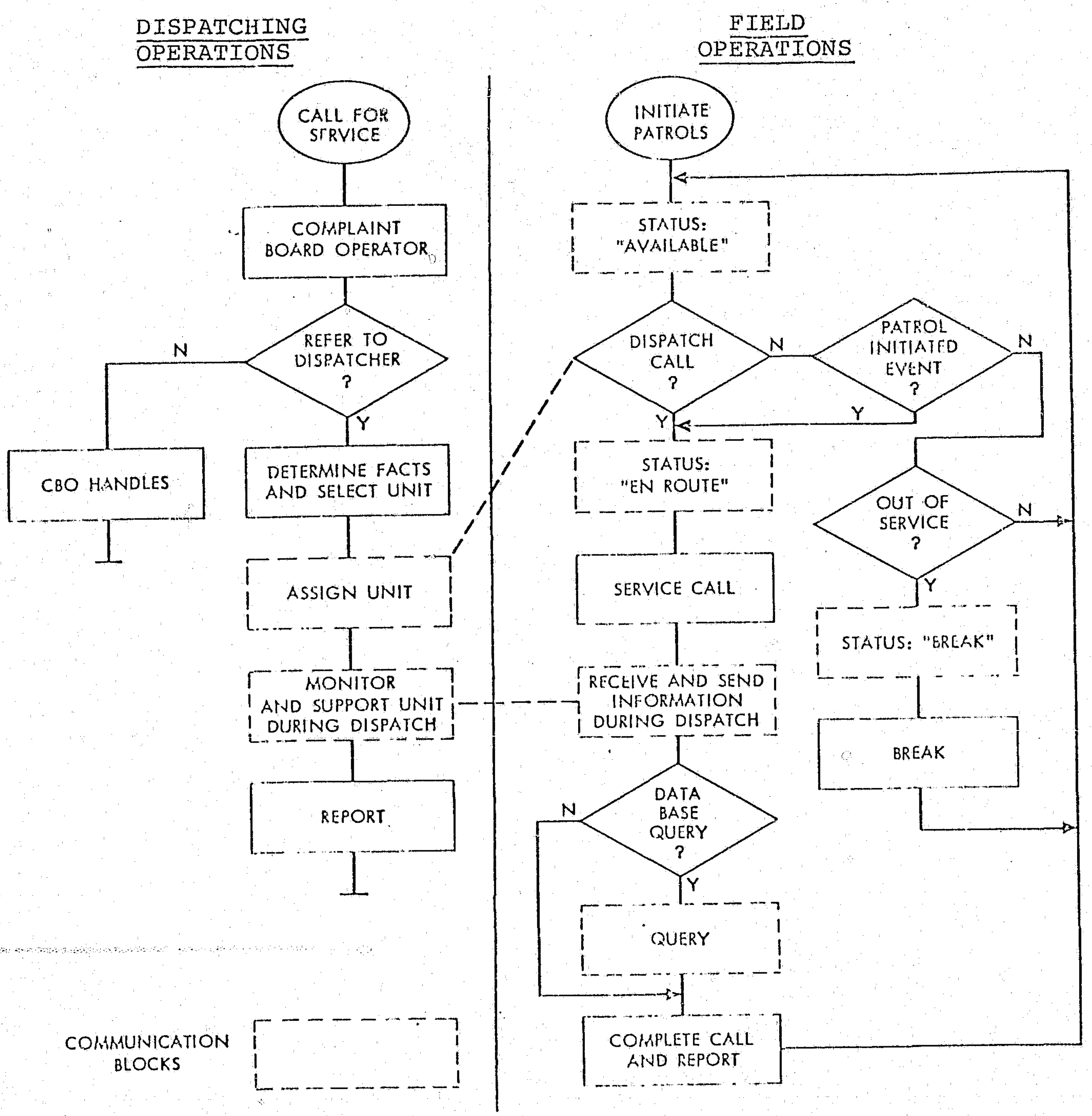
Elements of Patrol Allocation Plans

A major factor in determining the efficiency and effectiveness of the police is the manner in which available patrol resources are allocated. A complete plan for allocating or deploying patrol units to "cover" a specified jurisdiction usually includes the following elements:

- designation of the number of officers on duty (by time of day and day of week);
- designation of the types of patrol units to be fielded (one-man or two-man cars, foot patrols, motorcycles, report cars);
- designation of the number of units to be assigned to each region* within the jurisdiction;
- assignment of patrol units to geographical beats (districts);

---

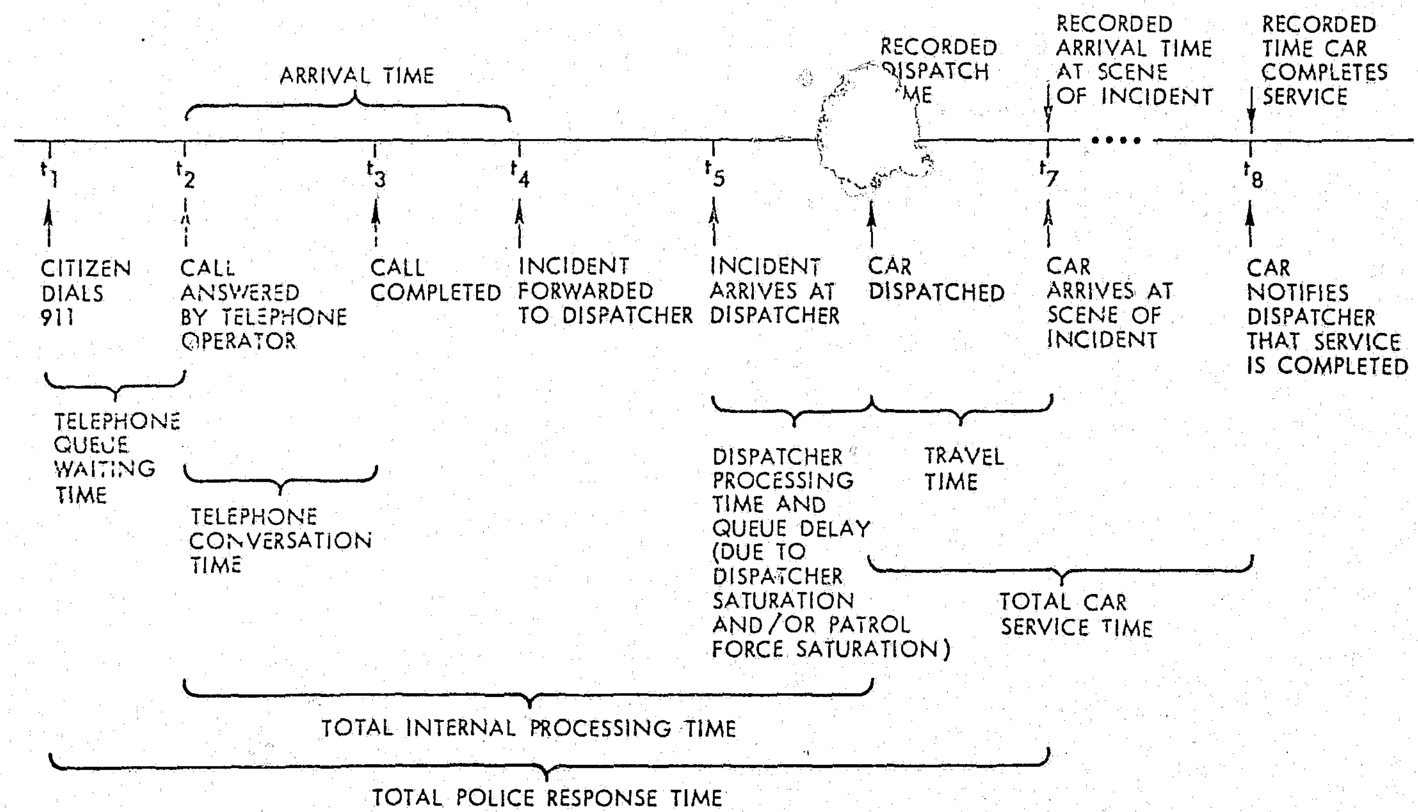
*Associated with each patrol unit is an area usually termed a beat or district in which that unit has preventive patrol responsibility; a reporting area is a sub-area within a beat and is used as the smallest geographical unit for aggregating statistics on calls for service and preventive patrol coverage; and a region is a group of beats administered as an autonomous field operations territory.



Source: R. L. Sohn and R. D. Kennedy, Patrol Force Allocation for Law Enforcement - An Introductory Planning Guide, JPL 5040-18, Pasadena: Jet Propulsion Laboratory, February 1976.

Figure 1-1

EVENT SEQUENCES FOR DISPATCHING AND PATROL OPERATIONS



Source: R. L. Sohn and R. D. Kennedy, Patrol Force Allocation for Law Enforcement - An Introductory Planning Guide, JPL 5040-18, Pasadena: Jet Propulsion Laboratory, February 1976.

Figure 1-2

EVENTS INVOLVED IN THE ARRIVAL AND SERVICING OF A CALL FOR POLICE SERVICE

- scheduling of patrol manpower (assignment of officers to shifts and designation of on-duty and off-duty days for each officer);

- policies for dispatching calls for service (number and selection of units to be dispatched, priorities to be assigned to calls, procedures for servicing queued calls); and

- procedures for redeploying resources when units are out of service or otherwise unavailable to respond to calls for service.

It can be seen from the above that the design of police beats is only one of many elements in a comprehensive patrol allocation plan. Beat design is directly related to other aspects of patrol allocation in several ways. The number of beats to be designed for a given region is dependent upon the number of patrol units to be assigned to the region. Not all available patrol manpower will necessarily be assigned to patrol units, and some patrol units may be assigned specialized duties such as crime-specific patrol or provision of back-up relief and assistance for beat units. Further, the number of time periods for which separate beat plans must be designed is dependent upon the degree of fluctuation in patrol strength by time of day and day of the week.

Criteria Used in Assessing Patrol Allocations

Ideally, patrol allocation plans should be evaluated in terms of their effect upon the attainment of police agency goals, such as crime deterrence and preservation of the peace. Unfortunately, these goals are usually stated in general terms only, and few, if any, reliable methods exist for operationalizing and measuring the impact of patrol allocation changes upon these goals. Consequently, the evaluation of allocation alternatives has been based upon direct measures of performance which experience and informed judgement have shown to be desirable. The most commonly used performance criteria include the following:

- workload balance among patrol beats and units;

- response time to calls for service (length of time callers must wait for a patrol unit to arrive);

- ease of access and patrol within each region;

- frequency of interbeat dispatching (assignment of units to calls originating outside of their assigned beats);

- time available for patrol-initiated activities (preventive patrol, patrol-initiated investigation, traffic enforcement, interaction with citizens);

- personnel and equipment costs;

- ease of administration and supervision (degree to which officers work with the same supervisors in the same areas and on the same shift each time they are on duty, number of distinct beat plans and manning levels, simplicity of patterns of on-duty and off-duty days);

- officer safety considerations (availability of back-up assistance, ease of radio communication, availability of unit location information);

- officer satisfaction;

- citizen expectations regarding response time and frequency of patrol;

- adequacy of patrol coverage in areas with special problems; and

- impact of allocation plan upon other areas of police operation, such as investigations and communications.

In addition to these criteria, several others sometimes are applied to patrol beat designs. For example, beat boundaries may be drawn along major streets and areas of high service demand to facilitate the use of officers from two or more beats to respond to calls in these areas and to assist each other. Preservation of the integrity of ethnic or cultural neighborhoods is also used as a beat design goal; this is effected by placing several small neighborhoods within one beat or by dividing larger neighborhoods into as few beats as possible.

Steps Involved in Designing Beats

Regardless of the specific criteria and methods, the design of police patrol beats usually includes the following steps:

1. Identify the regions and time periods for which distinct plans are to be designed; separate plans will be needed for each region or subcommand and may be needed for different times of the day and days of the week.

2. Determine the criteria to be used in choosing among alternative configurations for each region and time period.

3. For each region and time period, collect the data needed to operationalize the design criteria being used.

4. Define alternative beat configurations for each region and time period.

5. Select the final plans for each region and time period by comparing the data to determine which alternatives best meet the beat design criteria.

As discussed above, beat design represents only one element of a comprehensive patrol allocation plan. As a result, administrative considerations may also affect the final design of patrol beats. For example, field commanders may wish to limit the number of distinct beat plans to be used in each region to simplify patrol supervision and administration. A revised patrol allocation plan is also dependent upon the design and use of work schedules that will provide the desired number of on-duty officers during each watch.

Manual Beat Design Methods

Use of the patrol allocation criteria discussed above for beat design purposes is often very difficult because the criteria are interrelated and often conflicting. Design changes that produce an improvement in one criterion may detract from others. As a result, the beat design problem usually involves trading off selected goals against each other until a beat plan most acceptable in terms of the available patrol resources and operating policies is reached. This section reviews several manual design methods for dealing with these trade-offs.

Intuitive design. The design of patrol beats has been done most often on a purely intuitive basis, with the principal designer relying upon his or someone else's subjective knowledge of the jurisdiction and the workload distribution. This has facetiously been referred to as the "Bud Shell System" for designing beats, since the planner's tools are often only a six-pack of Budweiser beer and a Shell Oil Company street map. Such design efforts include the consideration of beat design criteria only on a subjective level.

The only prerequisite for the intuitive beat design method is some familiarity with the nature and workload of the jurisdiction. This requirement means that almost anyone in the police department with patrol experience can participate in the design effort. This process makes it easy to include command staff members in beat design decisions which in turn builds their investment in the final design and smooths the way for implementation of the plan. The fundamental problem with the intuitive design process, however, is that the designer has no way of estimating the performance characteristics of the plan before implementation. As a result, a plan may be designed and accepted that produces little or no beneficial change in the actual performance characteristics of patrol operations.

Manual workload balancing. Manual workload balancing uses various kinds of hand tabulated workload data, such as

Part I crimes and traffic accidents. These data are usually broken down by fixed geographical reporting areas (also called blocks, grids, areas, zones, or atoms). For each region and time period being examined, the basic steps in designing a beat plan with these data are:

- Compute the percentage of total workload for each reporting area.

- Beginning at the edges of the command, combine adjacent reporting areas into beats in such a way that the number of beats is equal to the number of patrol units available and all the beats have roughly equal workloads. (A policy of one unit for each beat and non-overlapping beats is assumed here for purposes of simplicity.)

- If several plans are produced which satisfy the workload balancing requirement, these alternatives can be evaluated using other design criteria. 3, 10, 28*

<u>Hazard formulas</u>. Hazard formulas follow the same procedures as workload balancing. In place of balancing empirical beat workloads, however, the goal is to balance the potential need for police service in each beat. This is done by listing the crime hazards present in each reporting area, assigning a weighted score to each type of hazard, and totaling the weighted scores for each reporting area. The types of hazards used may include the number and type of commercial establishments, the number of bars, the number of street miles, etc. The result is a hazard score or index for each area. Beat boundaries are then drawn so that all of the beats have approximately the same hazard score. (The hazard score for a beat is based on the sum of the hazard scores associated with each area in the beat.)

<u>Advantages of manual methods</u>. Foremost among the distinct advantages to the use of manual beat design methods is the absence of a need for computer hardware or data processing services. Although manual methods can be supported by computer-tabulated workload data, the actual design calculations can be done by hand or with a desk calculator. Also, since manual methods are easily explained to field personnel, it is relatively simple to obtain input from patrol officers, based on their personal knowledge of a region's crime patterns, access routes, etc.

<u>Problems with manual methods</u>. Major problems and limitations exist with manual beat design methods, including the following:

- Manual calculations can be tedious and time-consuming (and therefore expensive in terms of staff time), especially if several different plans must be designed

---

*Numbers refer to the references listed at the end of this report.

for several regions. Also, only a limited amount of field performance data may be conveniently utilized, even if considerably more information is available.

- Manual calculations cannot be used accurately or conveniently to trade off one design criterion against another; no practical methods exist for manually estimating the amount of cross-beat dispatching, the percentage of calls likely to be delayed, or average interbeat travel times.

- The assignment of weighted scores to crime hazards is itself a subjective process which may ignore the fact that low-hazard incidents often consume considerable amounts of patrol officers' time.

- Balanced beat workloads do not necessarily result in balanced patrol unit workloads. A unit in a centrally-located beat will be the dispatcher's second choice for more calls than will be a unit in a peripheral beat; thus, although both beats may share equivalent call-for-service rates, the central unit will have a higher workload due to a greater amount of interbeat dispatching.[19]

- Workload and hazard formulas do not reflect the fact that the number of units needed to service calls does not increase at a rate proportional to increases in the arrival rate of calls for service (i.e., a command with twice the rate of calls for service does not require twice as many units to give equal service).[20]

Computer-Based Models of Patrol Operations

Within the last decade, there has been considerable interest in the development of computer-based models of patrol operation. A computer model uses mathematical logic and formulas to define relationships between variables; such models can be used to provide insights into the consequences of alternative patrol operations decisions.

Reasons for using computers. Computerized models of patrol operations are used as a matter of necessity and convenience:

- Computers can solve complex mathematical problems with great speed.

- Computers can analyze many more deployment alternatives and design criteria than is possible when working by hand.

- Computerized beat design programs can be useful even if the user does not have a thorough understanding of how all of the calculations are performed.

- Many police departments now have routine access to data processing services.

- Computer printouts can often be used as charts, tables, or maps without additional work.

<u>Disadvantages of using computers</u>. Disadvantages of using computer-based models result mainly from their complexity and cost:

- Computer hardware and commercial data processing are expensive to purchase or lease.

- Many computer models require large amounts of input data which are not routinely collected in many police departments.

- Computer calculations are often difficult for patrol personnel to understand and therefore may not be accepted or trusted.

- Sophisticated analytical skills may be required.

<u>Currently available field operations models</u>. Reference 6 presents a comprehensive review of the types of computer-based police field operations models which have been developed. Those most relevant for users of the hypercube programs are described in the following paragraphs.

Patrol car allocation models specify the number of patrol cars that should be on duty in each patrol region at various times of the day on each day of the week. They can be used to analyze policy issues of the following types: (1) determining the total number of patrol officers a department should have, (2) allocating a fixed number of officers among distinct geographical regions, (3) determining how many officers in a region should work each tour or shift, and (4) determining the hours at which shifts should begin.

District design models are used for evaluating alternative district boundaries, car assignments to districts, and dispatching policies. They are most readily used when the number of patrol units to be fielded for each day of the week, region, and shift have already been determined by some other method, but it is also possible to use them as patrol car allocation models. (Hypercube is the only available documented model of this type.)

Manpower scheduling models are used to determine which days of the week each officer should work and be off duty, and when he should rotate from one shift to another. These models are especially useful in planning work schedules when the number of on-duty officers varies by day of the week and shift. They also can yield improved schedule characteristics when manning levels are uniform by shift and day of the week.

CHAPTER II

OVERVIEW OF THE HYPERCUBE SYSTEM

This chapter describes the capabilities and limitations of the hypercube system, and briefly discusses alternative ways in which the system can be used. Factors to be considered in assessing the feasibility of using the hypercube system in an individual department are also identified.

A. Basic Features of the Hypercube System

The hypercube system is a computerized representation of the hypercube queuing model developed by Dr. Richard Larson at the Massachusetts Institute of Technology. The model is used primarily to analyze alternative patrol policies and beat configurations, although it can also be used as a patrol car allocation model. While the model is lacking in prescriptive or optimization features, its descriptive capabilities are extensive. In particular, the model estimates the following field performance statistics for a beat plan and patrol policy described in the input to the hypercube software:

- average workload (e.g., fraction of time patrol units are busy) throughout the region being analyzed, as well as the workloads associated with each unit, beat, and reporting area in the region;
- average travel times to calls for service throughout the region, in each beat and reporting area, and to calls handled by each unit;
- average fraction of dispatches that are interbeat (i.e., dispatches that require the assigned unit to travel to an incident location not within that unit's beat) for each unit, each beat, and the entire region;
- fraction of calls throughout the region and in each reporting area to which a unit other than the closest available unit is dispatched; and
- fraction of calls for service that occur when no unit is available.

In order to compute these performance statistics, a number of simplifying assumptions about the nature of patrol operations, demands for service, etc. have been incorporated into the model. These include the following:*

---

*See the report Instructional Materials for Learning to Use the Hypercube Programs for Analysis of Police Patrol Operations for a more complete list and discussion of hypercube assumptions.

- The average number of calls for service received in a region for a watch can be accurately predicted by using historical data, even though the time intervals between call arrivals are random.

- The average time required to service calls in a region, from time dispatched to time cleared, can be accurately predicted by using historical data even though the service times for individual calls are random.

- Average service times do not vary significantly by beat.

- Travel time, from dispatch to arrival, accounts for only a small portion of total service time.

- Patrol activities resulting from officer-initiated and administrative work can be modelled in the same way as calls for service.

- The network of streets in the region is basically rectangular, such that travel distances can be computed by summing the distance travelled in each of two perpendicular directions.

- Only one patrol unit is dispatched to each call for service.

- Once dispatched, units are never reassigned to more serious calls.

- Calls for service received when no units are available are either assigned to backup units not explicitly represented, or queued and serviced later on a first-come, first-served basis.

- The time required for internal processing of incoming calls by telephone operators and dispatchers prior to dispatching a unit or queuing the call is insignificant compared to the time required to service the call.

In most departments, some of these assumptions will not be completely valid. In addition, much of the input data required by the model may be unavailable in some departments and will need to be estimated. As a result, the field performance statistics obtained from the hypercube model should be interpreted in a relative, rather than in an absolute, sense. That is, performance estimates based on a hypercube analysis are most meaningful when each of two or more alternative patrol policies and/or beat configurations are analyzed and the results compared to determine which alternative best satisfies department objectives--for example, balanced unit workloads, or minimal interbeat dispatching. Absolute agreement between hypercube performance estimates and observed field performance, however, should not be expected.

Nevertheless, comparative use of hypercube statistics can provide tentative answers to many questions of interest to department planners and field commanders. For example:

- Is one set of beat boundaries "better" than another set in terms of established department objectives?
- How will field performance be affected by anticipated increases in the numbers of calls for service, or by a decreased call-for-service rate resulting from the screening of low priority calls?
- Will significant improvements in field performance result if automatic vehicle location equipment is installed?
- What effect will a change in the distribution of preventive patrol coverage have on the various field performance measures?
- How will field performance by affected by alternative dispatching policies, such as dispatching the "closest" available unit rather than an available beat unit, or by the use of special units to handle calls arriving when no response units are available, rather than queuing the calls until a response unit does become available?

The use of the hypercube system as a planning tool to aid department planners in the beat design process is schematically depicted in Figure 2-1.

B. Versions of the Hypercube System

This section describes alternative ways in which police departments can access and use the hypercube system. Specific topics discussed include available versions of the system, and alternatives for implementing and operating the software.

All current versions of the hypercube system can be operated in one of two operating modes: either interactively or non-interactively. Hypercube systems designed to operate interactively consist of two components. The first, termed the "MONITOR" by its developers, enables a police planner to describe the patrol policy and beat configuration being analyzed in a "conversational" way by responding, via a teletypewriter-type data terminal, to questions posed by a computer. The computer then analyzes the planner's response, ensures that the response is consistent with previously supplied information, and performs other error-checking functions. The planner is informed of any error found in his response, and corrects the error before proceeding. Once a valid response has been elicited, planner-computer interaction continues until the patrol policy and beat configuration have been completely specified. At that point, the computer transforms the information supplied

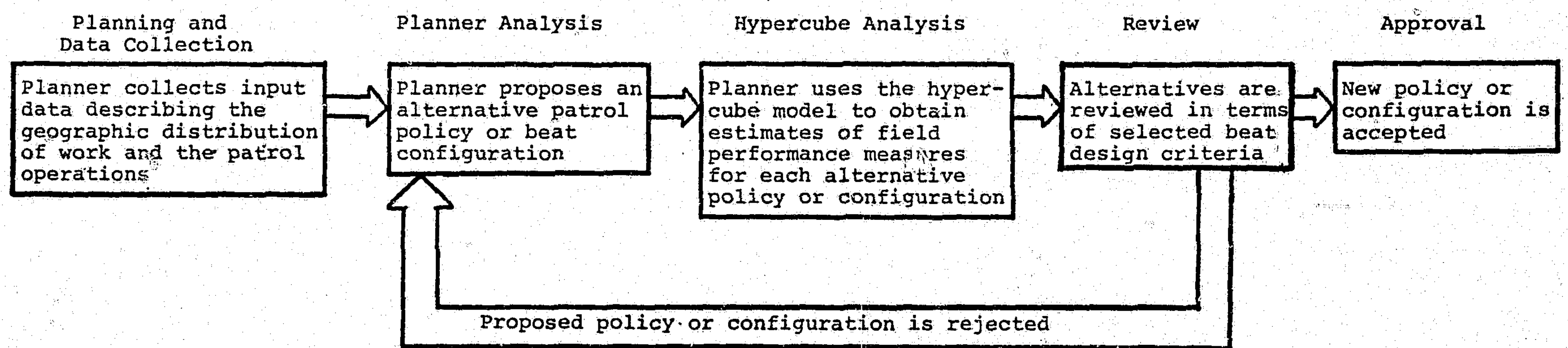


Figure 2-1

ITERATIVE DESIGN PROCESS USING THE HYPERCUBE SYSTEM by the planner into a format required by the second component of the hypercube system, termed "HYPERCUBE," which computes field performance estimates for the policy and configuration described.

The hypercube "MONITOR" component is not used with non-interactive versions of the hypercube system. In these versions, the planner must specify the patrol policy and beat configuration directly in the format required by the "HYPERCUBE" component, either by coding and keypunching the information on punched cards or, by entering the data into a storage area of the computer system using a data terminal. In either case, the computer does not interact with the planner. In particular, the data items are not checked for errors, the information is not reformatted, and tutorial assistance accessible to users of the "MONITOR" is not available.

With non-interactive versions of the system, the "HYPERCUBE" component obtains all of the information it needs to compute field performance estimates from the formatted input file kept either in the computer's auxiliary storage area or on punched cards. Consequently, no interaction is required between the planner and the computer system. Operation of the system can be initiated by a user connected directly to the computer via a data terminal with the results available immediately, or it can be scheduled for deferred initiation, usually overnight, with the results available at a later time. The former type of operation is termed "on-line," while the latter is termed "batch."

In the remainder of this chapter, versions of the hypercube software are classified as "interactive" if the "MONITOR" is used to describe the patrol policy and beat configuration and "non-interactive" if the "MONITOR" is not used.

Currently, there are four versions of the hypercube software available. They are:

- M.I.T./Rand hypercube system - This is the original hypercube system developed through grants from the National Science Foundation and the U.S. Department of Housing and Urban Development; to date it is the most widely-distributed version.

- M.I.T. advanced hypercube system - This system consists of an advanced version of the original M.I.T./Rand system which incorporates automatic vehicle location and expanded user control of the types of output produced.

- TIPPA advanced hypercube system - This is an adaptation of M.I.T.'s advanced system that has evolved during TIPPA's field testing of the hypercube model. It contains several features lacking in the M.I.T. system (e.g., the utilization of user-supplied terminology), and incorporates many improvements suggested by police planners during the field tests. This version of the software is especially suitable for implementation on the National CSS time-share system.

- Texas A&M police officer deployment system (PODS) - This system was developed through a grant from the Criminal Justice Division, Office of the Governor of Texas. A version of the hypercube model forms one component of this system. Other components are capable of prescribing beat plan modifications to balance beat workloads or beat travel times, forecasting workloads, and producing maps showing beat boundaries.

The major differences between these four versions of the hypercube system occur with respect to the following:

- Interactive or non-interactive - Does the system include a version of the interactive "MONITOR?"

- Computer programming language - Is the software written in PL/I or in COBOL? (This is an important difference since some computer systems may not accept some languages.)

- Approximate or exact hypercube model - Does the system support the exact model, the approximate model, or both? (The approximate model utilizes some approximations in its computations which greatly simplify the calculations and reduce costs, and which generally produce results within a few percent of those obtained using the exact model. The exact model, on the other hand, supports several advanced hypercube features, such as variable unit service times and dispatching based on automatic vehicle locators.)

- Limitations on problem size - What limitations are placed on the size of regions (i.e., on the number of reporting areas) and on the size of beat plans (i.e., on the number of beats) that can be analyzed?

The differences among the four hypercube systems are summarized in Table 2-1.

In some cases, a department planning to implement the hypercube system will have no choice in selecting the version to be used. For example, if hypercube is to be implemented on a computer system supporting COBOL, but not PL/I, the Texas A&M version will be the only alternative. In other cases, several of the versions may satisfy the department's needs. When this occurs, the following rule of thumb should be applied: select the version providing all required

Table 2-1

CHARACTERISTICS OF CURRENTLY AVAILABLE VERSIONS OF THE HYPERCUBE SOFTWARE

	Software Version			
	M.I.T./Rand	M.I.T.	TIPPA	Texas A&M
Interactive or Non-Interactive	Non-Interactive	Non-Interactive	Interactive	Non-Interactive
Programming Language	PL/I	PL/I	PL/I	COBOL
Approximate or Exact Model	Both	Both	Both	Approximate Only
Limitations on Problem Size[a]	200 reporting areas and 15 beats	200 reporting areas and 15 beats	Unlimited number of reporting areas and 34 beats	125 reporting areas and 25 beats

[a]Size limitations apply only to the approximate hypercube model. All versions of the exact hypercube model limit the number of beats to 15. In most cases, the limits specified can be relaxed through internal programming changes.

features, but as few unneeded features as possible.* Applying this rule will generally result in selecting the version which requires the least amount of computer resources, and which is the least costly to use. Figure 2-2 can be used as an aid in making the selection.

The hypercube software can be implemented on any data processing system which meets the following qualifications:

- The data processing system must have a compiler capable of translating the language of the software being implemented (i.e., either PL/I or COBOL) into a machine language understood by the computer.

- The data processing system must have sufficient core storage to analyze regions and beat plans of the size of interest. The version of the software developed at Texas A&M requires approximately 212K bytes** of core storage on an IBM 360/65 to analyze regions and beat plans with up to 125 reporting areas and 25 beats. For the other three versions, the amount of core storage required depends on the number of reporting areas in the region, the number of beats in the beat plan, the number of call arrival rates (workload levels) for which field performance estimates are to be computed, and the type of model used (i.e., approximate or exact). Tables A-1 and A-2 contain estimates of the core storage required to use the approximate and exact hypercube models in computing performance statistics for a single call arrival rate. These estimates include approximately 80K bytes of storage required for the operating system*** of the computer used during the field tests. In general, the amount required by other systems will be different.

- The data processing system should be locally accessible to police departments. That is, systems used for batch processing should have a nearby office, and systems used "on-line" should be accessible via telephone--preferably through a local or toll-free exchange.

---

*Some departments may wish to use the TIPPA version, rather than apply this rule, because (1) the interactive features of this version make it especially suitable for planners inexperienced in the use of computer-based models, and (2) since this version has been implemented on a commercial data processing system implementation costs and effort can be avoided.

**One K-byte of computer storage equals 1024 bytes.

***The operating system refers to the management routines used by the computer to perform input, accounting, and storage allocation functions.

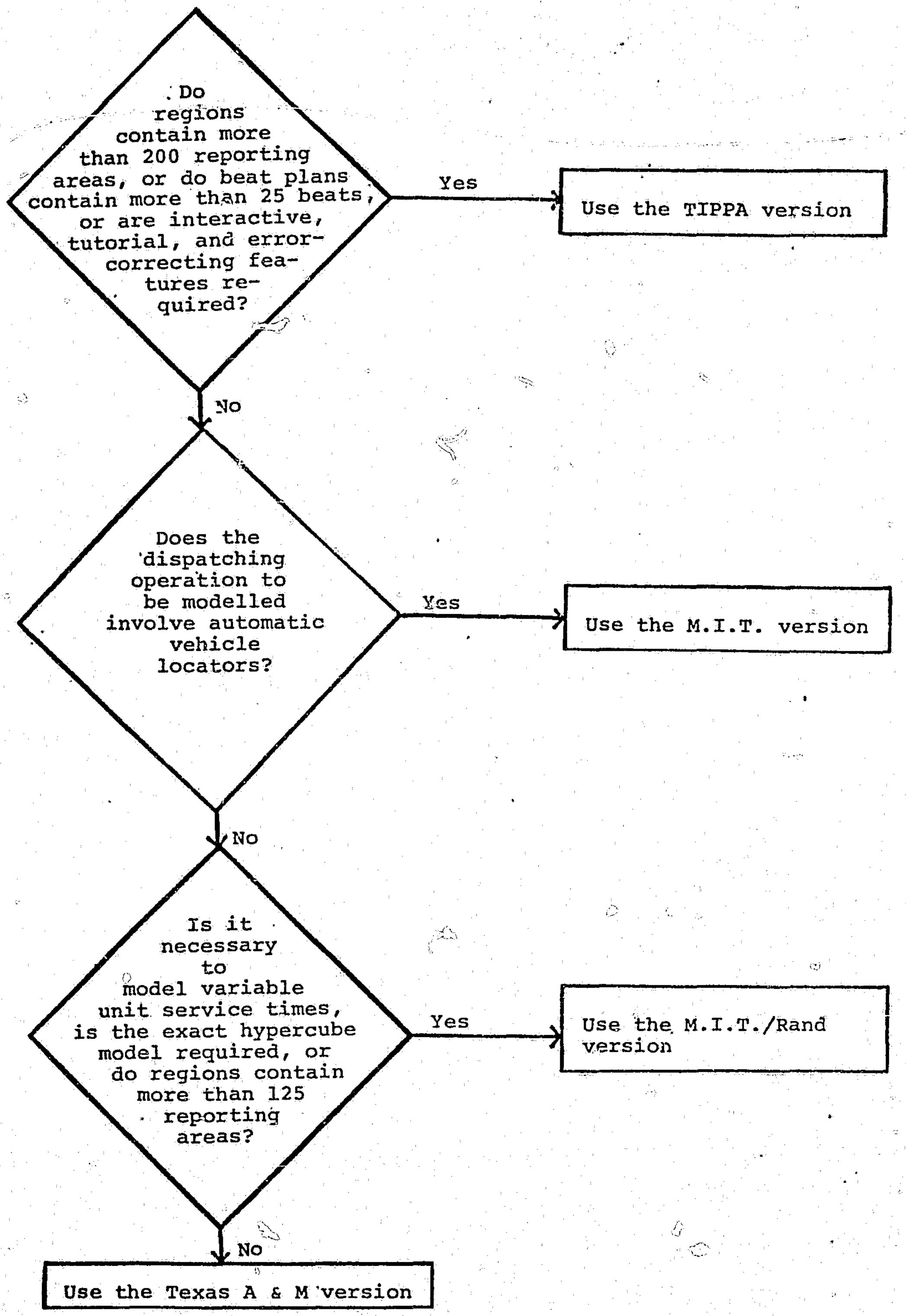


Figure 2-2

SELECTING AMONG AVAILABLE VERSIONS OF THE HYPERCUBE SOFTWARE

- If the hypercube system is to be used interactively, the data processing facility should have the hardware and software necessary to support interactive operations.

Implementation alternatives include the following:

- In-house data processing facilities - Use of an in-house computer offers the potential for low cost data processing services and readily available technical assistance in the area of software implementation. The major drawbacks to using in-house facilities are: (1) department hardware is unlikely to support interactive operation, (2) software written in the PL/I programming language is unlikely to be supported, and (3) core storage capacity is likely to limit the size of the regions and beat plans that can be analyzed.

- Commercial data processing facilities - Several commercial time-share systems are suitable for implementing both the interactive and non-interactive versions of the hypercube software written in the PL/I language, and most are capable of supporting the non-interactive COBOL version. These time-share systems provide convenient access to data processing services via data terminals and standard telephone networks. As a result, even police departments without internal data processing capabilities can use the hypercube model by paying for only the services and equipment used. Nevertheless, the implementation alternative is relatively expensive due to the high cost of the services and on-line storage of the programs and data. Also, unless the system can be accessed through a local or toll-free telephone exchange, substantial communications costs may be incurred.

- University-based data processing facilities - Many university-based computer centers are able to support non-interactive versions of the hypercube system, and some can support interactive versions in a time-share environment; core storage capacity, however, may be less than that available on commercial systems. Because these data processing services are geared to the university community, the amount of data processing services and technical assistance that can be provided to organizations not affiliated with the university may be limited. Furthermore, universities do not provide toll-free access to their services, and remote users may experience long-distance communications costs. On the other hand, university charges for data processing services are usually substantially less than those of commercial vendors.

- Consultants - Several management consulting firms have implemented versions of the hypercube software and will provide technical assistance for the analysis and design of patrol policies to police agencies. While such consulting services can be expensive, this alternative can partially relieve a police department from the effort and expense of implementing, testing, and learning to use the hypercube system.

C. Advantages and Disadvantages of Using the Hypercube System

The advantages and disadvantages of using the hypercube system are briefly summarized in this section. Among the advantages are:

- Because of built-in tutorial and error-checking capabilities, the interactive version of the hypercube software is relatively easy to use; as a result, extensive data processing experience is not a prerequisite to achieving successful hypercube analyses.

- The hypercube model provides estimates of field performance of proposed patrol policies and beat configurations not otherwise available to police planners.

- Since the police planner can suggest alternative policies and configurations, the hypercube model allows departmental constraints and objectives, not explicitly represented in the model, to be included in the design process.

- Use of the hypercube programs enables the planner to estimate the effects of policy and deployment changes on field performance before such changes are actually implemented. This can avoid costly and disruptive field experimentation.

- Efficient use of the software may reduce planning costs.

- Data bases created as a result of hypercube analyses may prove useful in other planning and evaluation efforts.

- The interactive versions of the software provide a useful training tool that can be used to teach planners the fundamental concepts of field patrol operations.

- The hypercube programs automate most calculations normally required to design beats manually; as a result, they can be useful to departments otherwise uninterested in sophisticated beat design and analysis.

The disadvantages of using the hypercube system to design beat configurations and analyze patrol policies include the following:

- Computer costs can be high, especially if data processing services must be purchased commercially and the software is used carelessly or inefficiently. Consequently, a substantial data processing budget may be required.

- Data collection can be costly and time consuming, especially when required data are not available. While input data can often be estimated rather than measured, this may destroy confidence in the model's performance estimates.

- To use the hypercube system efficiently, the planner must familiarize himself with the capabilities, assumptions, and limitations of the model. If required, training and other forms of technical assistance may not be free. If the planner experienced in the use of hypercube subsequently leaves the department, the investment in his training is lost.

- Since the hypercube system will be used infrequently (probably only once or twice per year), department administrators may feel that the benefits do not justify the effort and expense associated with training, data collection, data processing, and technical assistance.

- Results of hypercube analyses may be rejected by field operations personnel merely because they are computer-based, or because they ignore important features of the department's patrol operations.

D. Assessing the Feasibility of Using the Hypercube System

Because of the substantial costs and effort that can occur, it is important to determine whether the hypercube system is a feasible and potentially beneficial planning tool for a department. The past experiences of hypercube users indicate that not all departments which begin a hypercube analysis will complete the project. It can be argued that departments that fail to complete the analyses may still benefit from the data collected for future planning and evaluation of patrol operations, and that department planners have been exposed to valuable training. However, it is doubtful that department administrators will feel that the expenditure of department resources was justified unless improved beat plans are implemented, or the adequacy of current plans is clearly demonstrated.

Circumstances in which a police department is most likely to benefit from using the hypercube system are summarized below. While all the circumstances listed are not prerequisites for successful policy analysis and beat design, some combination of them has usually been lacking in those departments that have failed to benefit from using the hypercube model:

- <u>Recognized need to analyze the patrol plan</u> - A need to analyze the patrol plan will be most apparent in departments experiencing heavy workloads, frequent queuing delays, and other field operations problems. Departments which are generally satisfied with their patrol policy and beat structure are unlikely to expend the effort required to follow a hypercube-assisted beat design project through to completion.

- Cooperation and communication between field, support, and planning personnel - Beat configurations should not be designed without cooperation between planning, field, and, where applicable, data processing personnel.

- Agreement among administrative, field, and planning personnel on a set of department objectives for patrol operations.

- Design objectives other than balanced beat workloads - Departments interested only in balancing beat workloads should consider simpler and less costly manual design techniques.

- Adequate time for analysis - Allowing insufficient time for planning, data collection, analysis of hypercube output, etc. leads to inefficient use of the hypercube system, increased costs, and erroneous results.

- Acceptance of computers and mathematical modelling as reliable planning tools.

- Access to in-house data processing, or a sufficient budget for purchasing commercial services.

- Availability of data and a willingness to commit department resources to data collection efforts - See Chapter IV.

- Patrol operations satisfying the assumptions of the hypercube model - The hypercube assumptions listed earlier in this chapter must apply reasonably well to the department's patrol operations in order to insure reliable and valid results.

Methods of dealing with some of these issues are discussed in Appendix C.

CHAPTER III

ESTIMATING THE COSTS OF USING THE HYPERCUBE SYSTEM IN AN INDIVIDUAL POLICE DEPARTMENT

This chapter provides guidelines for estimating the costs of using the hypercube system to analyze patrol policies and beat configurations. The principles discussed below and in Chapter II are illustrated by citing the experiences of two California departments which participated in the field test project: Fresno and Pasadena.

A. Estimating the Costs

The costs of using the hypercube system fall into three major categories: personnel, data processing, and technical assistance. The activities in each category include:

- Personnel - manpower costs associated with planning, training, data collection, data analysis, and beat plan implementation.

- Data processing - costs associated with setting up, maintaining, accessing and using a data processing facility for training and data collection; and with setting up, maintaining, and using the hypercube system for beat analyses.

- Technical assistance - costs for training materials; and for technical assistance with project planning, training, data collection, use of the hypercube programs, and interpretation of hypercube results.

Each of these costs is discussed below.

Personnel Costs

The results of the hypercube field test project indicate that departments will require up to six months to design and implement a beat plan using the hypercube system. During this period, one or more persons will have to spend considerable time planning project activities, learning to use the hypercube system, monitoring data collection efforts, performing hypercube analyses, coordinating in-house review and approval of new plans, and initiating appropriate implementation procedures.*

The actual time required to design and implement a new beat plan depends on:

- familiarity and experience of key personnel with computerized design or decision models;

---

*Most of these activities are not peculiar to a hypercube beat design analysis, but are in fact present for most manual and computerized design procedures.

- accessibility of data required to use the hypercube model;

- accessibility of data processing services; and

- extent of cooperation and communications between personnel responsible for the design, approval, and implementation of the new beat plans.

Table 3-1 presents estimates of elapsed time for each of the major tasks in a beat design project. The time estimates for each task are based on results reported by eight field test departments. The table indicates that elapsed times range from 8 to 28 weeks for a complete beat design effort. The lower estimate is very optimistic. It assumes that at least one person is working full-time on the project, and is only applicable to departments with trained personnel, specially designed data sources, and readily accessible data processing services.

The higher time estimate is applicable to departments using the hypercube system for the first time. This estimate assumes that the project coordinator devotes only part of his time to the project (e.g., one-third or one-half time), and that the project encounters delays familiar to every police planner: training materials are delayed, special data collection efforts are required, data processing turnaround is slow, in-house review of new beat plans is cumbersome, and new design criteria are introduced in a manner which requires several cycles before final approval is obtained.

The experience of the field test project indicates that estimating the time required for data collection is often a difficult task. The ability to obtain accurate estimates depends largely on the quality of the data assessment made during the planning task. This assessment should answer the following questions for each data item required by the hypercube program:

- What source documents contain the data item?

- How accessible are those documents?

- What procedures will be needed to obtain and translate each data item from source document into hypercube-usable form (e.g., sample size, collection procedures and forms, data processing support)?

Table 3-2 summarizes the number of man-weeks spent by the departments in the field test project to collect data for the hypercube system. Five of the eight departments required from one to four man-weeks. The three departments requiring more than four man-weeks usually utilized two or

Table 3-1

ESTIMATED NUMBER OF WEEKS
REQUIRED TO COMPLETE THE MAJOR TASKS
OF A HYPERCUBE BEAT DESIGN PROJECT[a]

Task	Activities	Number of Weeks[b]
1. Training	Study hypercube documentation; learn the assumptions of the model, the data required, and how to use the computer programs.	2 - 4
2. Planning	Assess department operations, data sources, and data processing capabilities; organize project task force.	2 - 4
3. Data Collection	Plan and coordinate the collection of data required by the hypercube programs.	1 - 8
4. Data Analysis	Prepare the input data, run the hypercube programs, and analyze the output.	1 - 8
5. Beat Plan Implementation	Coordinate in-house review of proposed plans, and all documentation, operations, and policy changes required to accommodate the approved plan.	2 - 4
Total Beat Design Effort		8 - 28

[a]The elapsed time estimates are based on the experience of eight police departments which participated in the field test project.

[b]The lower estimate for each task assumes that at least one person works full-time on the project. The higher estimate for each task assumes that the project coordinator devotes only one-third or one-half time to the project.

Table 3-2

NUMBER OF MAN-WEEKS REQUIRED TO COLLECT
DATA FOR THE FIELD TEST PROJECT

Number of Man-weeks	Number of Departments
1 - 2	2
3 - 4	3
5 - 6	1
7 - 8	1
9 - 10	1

Average = 4.6 man-weeks

three coders for two or three weeks in order to extract the raw data from department files. The departments utilized an average of 4.6 man-weeks for data collection.

Data Processing Costs

Data processing costs during a beat design project can occur during the data collection task and during the data analysis task.

The extent to which a department may use data processing to facilitate data collection depends on:

- the availability of experienced personnel to coordinate the data processing,
- the accessibility and cost of data processing services, and
- the trade-off between the cost of keypunching and data processing to obtain estimates based on large samples, and the cost of manually obtaining less accurate estimates based on much smaller samples.

Data processing costs associated with data collection can be estimated only on an individual department basis. The field test project offered little guidance in this area since the TIPPA staff provided data processing support for several departments to facilitate their participation in the project. The project does suggest, however, that the beat design project coordinator should carefully assess data needs and review all data processing options, including the option of avoiding data processing during the data collection task, before proceeding.

Data processing costs for the data analysis task depend on the version of the hypercube software used and the implementation option selected (i.e., the type of computer facility used). These costs consist of the following components:

- Equipment and supplies - If data terminals are rented, shipping charges may be incurred, and service, insurance, and supplies will be required.

- Set-up charges - Unless an implemented version of the hypercube system is available, a copy of the software must be obtained; the programs must be compiled (translated) into an executable form and tested; and supporting software must be developed to facilitate data input, system usage, and output retrieval.

- Communications costs - When remote data processing services are accessed, long distance telephone charges may result.

- Storage charges - Commercial and university-based data processing systems usually charge users for the on-line storage of their programs and data.

- Computer usage costs - Commercial and university-based systems usually charge users for the amount of time they are connected to the central site computer, the amount of computer resources they use in their processing, and the amount of input and output operations required. Users of in-house facilities may also be charged for the amount of processing required, especially if the facilities are maintained by, or shared with, other agencies.

These cost components are further classified according to whether each is usage-dependent or not--that is, whether each depends on one or more of the following problem attributes:

- Number or regions to be analyzed - the number of autonomous field operations regions, and the number of distinct workload distributions in each (different workload distributions usually correspond to different watches or days of the week).

- Size of each region and the number of response units - the number of reporting areas in each region, and the number of response units assigned to each region.

- Number of iterations attempted for each region - the number of patrol policies and beat configurations to be analyzed with the hypercube system. This number should include one iteration to calibrate the hypercube model, and one iteration for analyzing the current patrol policy and beat configuration.

- Timeframe within which the hypercube analysis will be performed - the number of calendar months between the time the hypercube system is first used and the time all hypercube data processing will be completed, and the fraction of staff time to be allocated to the analysis.

Estimates of usage-independent costs are summarized in Table 3-3. The versions to which each cost applies are also indicated. These estimates are derived from costs experienced by the eight participating police departments. These costs are based on the suppliers used during the field tests (e.g., for equipment and data processing services), and on the rate schedules in effect at that time.

Once the input data required by the hypercube system have been collected, hypercube analyses proceed in two steps. First, an input file containing data describing the geography and relative workload of each reporting area in the region is created. Table A-3 shows the estimated cost of creating this file for various-sized regions.* When a region file already exists, the estimated cost of modifying reporting area workloads (geographic data are unchanged) is shown in Table A-4.

The second step involves the creation of an input file describing the beat configuration and patrol policy, the computation of hypercube's field performance estimates, and the retrieval of hypercube output. This step is performed once for each hypercube iteration in each region. Cost estimates for regions with various numbers of reporting areas and for beat plans with various numbers of response units are shown in Tables A-5 and A-6. The estimates in Table A-5 apply when performance statistics are computed on-line while those in Table A-6 indicate the reduced costs of making these calculations off-line in batch mode.

To use these estimates to predict the data processing costs for hypercube analyses, the following factors should be considered:

- The estimates shown were derived by assuming that costs increase linearly with the numbers of reporting areas and beats. This assumption appears to hold fairly well for the problem sizes reported in the tables; however,

---

*These and other usage-dependent data processing cost estimates presented in the remainder of this chapter are based on costs experienced during the field tests when most data were input interactively using the National CSS time-share system. For police departments planning to use the hypercube software in-house or on university-based systems, these estimates should represent upper bounds which probably greatly overestimate the actual costs. More realistic estimates can only be obtained by performing a hypercube analysis and comparing the actual and estimated costs. Similarly, costs of hypercube analyses on commercial time-share systems other than National CSS can only be accurately assessed by trial runs.

Table 3-3

USAGE-INDEPENDENT COSTS ASSOCIATED WITH THE HYPERCUBE SYSTEM

Type of Cost	Estimated Cost	Environments in Which Cost Applies
1. Equipment costs		
a. Rental of data terminal	$75 - $150 per month	Remote systems accessed from planner's office
b. Shipping	$40 - $60	Remote systems accessed from planner's office
c. Terminal service	$30 per servicing[a]	Remote systems accessed from planner's office
d. Terminal supplies	$55 - $70	Remote systems accessed from planner's office
e. Insurance	$30 per year	Remote systems accessed from planner's office
2. Set-up costs		
a. Copy of hypercube software and documentation	$50 - $200	Implementation on data processing system where hypercube is not currently available
b. Program compilations and testing	$400 (maximum)[b]	Implementation on data processing system where hypercube is not currently available
c. Development of facilitating software	$50 - $150	Systems to be accessed interactively or on-line
d. Monthly minimum charges	$100 per month[b]	Commercial systems only
3. Communications costs	Depends on locations of user and computer access points	Data processing systems accessed long distance via telephone
4. Storage charges		
a. Hypercube software	$88 per month[b]	Commercial and university-based systems only
b. Hypercube input and output	$44 - $110 per month[b]	Commercial and university-based systems only
5. Technical assistance	$125-$300 per day	

[a]All terminals used during the field test project required servicing two times or less.

[b]Based on rate schedule in effect for the National CSS time-share system in January 1977.

comparisons with empirical cost data indicate that the estimates are slightly low for the smaller problems and slightly high for the larger problems (the upper left-hand and lower right-hand portions, respectively, of Tables A-5 and A-6).

- The estimates assume that input files describing beat configurations are created by using the interactive "MONITOR" program; that performance statistics are computed using the approximate model; and that only region, unit, and district performance measures are listed.

- The estimates are based on the rate schedule in effect in January 1977 on the National CSS time-share system.

- The estimates have not been adjusted to include any overhead associated with using the hypercube system (e.g., inefficient use of the system, or runs aborted due to the user's error). The experiences of the field test participants suggest that this overhead can be substantial.

Technical Assistance Costs

Technical assistance costs include all costs incurred for documentation and training materials, training seminars or workshops, and consulting services used to support agency personnel during the beat design project. A considerable amount of documentation is available which describes the basic assumptions and theoretical foundations of the model, use of the hypercube programs, data collection procedures for the hypercube system, and analysis and interpretation of hypercube results. An annotated list of these documents is presented in Chapter IV. Departments should be able to purchase all relevant documents for less than $100.

The police personnel who participated in the field test project generally agreed that some formal training in the use of the hypercube system is a prerequisite to efficient use of the model.*

Formalized training in a classroom setting is available from several agencies, identified in Chapter IV. Only The Institute for Public Program Analysis offers more than a one-

---

*At least one person from each department in the field test project attended a five-day workshop on the use of the hypercube model. Most participants felt that five days of training represented a minimum level of instruction. Several participants suggested that future workshops be expanded to 10 days.

or two-day introduction to using the system. Tuition for these courses is usually between $300 and $600. Contracts with private consulting firms to provide individualized training sessions can run as high as $300 per day. Although the initial cost of such training may seem high, learning the hypercube system by trial and error can easily be more expensive in the long run.

The actual amount of training required is highly dependent on the experience and technical expertise of the person responsible for running the hypercube program and interpreting the results. Extensive self-instruction using hypercube documentation and training materials should be possible for persons with experience in using computer models.

Some departments may want to have knowledgeable persons from outside the department assist in some of the major tasks of a beat design project. Agencies from which such technical assistance can be purchased are identified in Chapter IV. Agencies such as The Institute for Public Program Analysis provide a limited amount of free technical assistance as part of their training programs. Other agencies may provide assistance only on a contractual basis. Fees charged vary considerably from agency to agency, and departments seeking such technical assistance should solicit estimates from several agencies before selecting one.

As with training, the amount of technical assistance that will be needed is highly dependent on the experience and background of department personnel, and to a lesser extent on the complexity of the beat design problem. The amount of training and technical assistance provided to the eight departments in the field test project is summarized in Table 3-4.

B. Hypercube Usage in Two Field Test Departments

This section briefly relates the experiences of two California police departments in using hypercube to analyze patrol policies and design new beat configurations. Emphasis is placed on those aspects which directly bear on the topics discussed above and in Chapter II.

Fresno

The City of Fresno covers an area of 54 square miles, and has a population of 175,000. Prior to initiating its hypercube-assisted beat design project in 1976, the Fresno Police Department had used the same beat configuration for over 10 years. This beat plan called for the deployment of approximately equal numbers of officers on each of three shifts, each day of the week. Additional manpower assigned to an overlay shift provided back-up assistance to beat cars during the last four hours of the afternoon shift and the first four hours of the midnight shift. Total patrol manpower numbered 137 officers.

Table 3-4

AMOUNT OF TRAINING AND TECHNICAL ASSISTANCE PROVIDED TO INDIVIDUAL DEPARTMENTS BY THE INSTITUTE FOR PUBLIC PROGRAM ANALYSIS DURING THE FIELD TEST PROJECT[a]

Activity	Man-Days
Initial Planning (orientation and data collection guidelines - May 1976)	1
Orientation Meeting (May 1976)	1
Data Collection Meeting and Follow-up Support (May-August 1976)	½ - 3
Training Workshop (June 1976)	5
Telephone Contacts (average of 10 contacts per department - June-October 1976)	1
Implementation Meeting (September 1976)	1
Summary	
Training	5
Technical Assistance	4 - 7
Total Man-Days	9 - 12

[a]Does not include a two-day advanced training and project evaluation workshop held in December 1976.

While the limitations of the manpower allocation plan (e.g., workload imbalances and frequent queuing of incoming calls) had long been recognized, previous analyses had failed to produce an adequate alternative. Hypercube was seen as an excellent tool for studying alternative beat designs because of its ability to show the interrelationships between workloads, response times, preventive patrol levels, and cross-beat dispatching. As a result, two members of the department's Administrative Services Bureau were assigned to work full-time on the beat design project from July through October 1976.

Data collection proved to be a fairly minor task in Fresno, since most of the data required as input to the hypercube system were available through the city's data processing center; some data did have to be adjusted to satisfy the assumptions of the model. For example, workload data were available by hour for each of Fresno's 249 reporting areas. Geographic data, however, had to be measured for these areas (see Chapter IV).

During a six-week period beginning July 1, 1976, department personnel, with limited technical assistance from TIPPA, analyzed alternative beat configurations for five different time periods. A preliminary version of TIPPA's hypercube software implemented on the National CSS time-share system was used. A total of 36 hypercube iterations were required to design new beat plans calling for from 13 to 29 beats for the five regions corresponding to the five time periods. Computer usage charges were approximately $3,400,* storage charges were $450, equipment and supplies cost $500, and communication charges were $600. Since an implemented version of the software was used, no set-up charges were incurred. Thus, data processing costs totaled nearly $5,000. In addition, a total of 25 man-weeks was expended for planning, training, data collection, data analyses, and beat plan implementation.

Prior to implementation on November 3, 1976, the proposed plans were reviewed by a departmental task force of represen-

---

*Most of the hypercube iterations were done on-line rather than in the less costly batch mode. An estimate of computer usage charges could have been derived beforehand by using Tables A-3, A-4, and A-5. For example, the cost of creating an input file describing the geography and workload of a region with 249 reporting areas would be estimated as $35 (Table A-3), and the cost of modifying the workloads in this file for the other four regions (time periods) as 4 x 18 = $72 (Table A-4). The cost of 36 on-line hypercube iterations could be estimated for a beat plan with 29 beats (for simplicity, the size of the largest plan is used): 36 x 70 = $2,520 (Table A-5). The difference between the actual cost of $3,400 and the total estimated cost of $2,627 is due to overhead (e.g., inefficient use of the system, runs aborted due to user error), and operating problems during the field test that subsequently have been corrected.

tatives from the patrol and communications divisions, police officers' association, and the Administrative Services Bureau. Despite a major reallocation of manpower among shifts and drastic changes in the beat plan, implementation proceeded with only a few minor problems.

Preliminary assessment of the new field operations plans indicates the following positive results:

- The fraction of calls for service held by dispatchers for more than three minutes because all units were unavailable decreased from 62.0 percent in October 1976 to 45.2 percent in November 1976.

- Under the old plan, often as many as 45 calls for service were held by dispatchers at the end of the afternoon shift. Under the new plan, the number held over for the incoming shift seldom exceeds five.

- Average travel time to calls for service appears to have decreased significantly.

- The manpower reallocation among shifts suggested by the hypercube study avoided the need to hire additional officers--a course of action management had previously assumed would be necessary to meet the heavy demand for service on some shifts. The estimated savings in salaries and fringe benefits is $200,000 to $350,000 annually.

The factors contributing to the success of the beat design effort in Fresno include the following:

- There was a recognized need to revise the department's patrol allocation and beat structure.

- Much of the data needed was readily available.

- The formation of a department task force to supervise the project helped assure cooperation and input from all bureaus affected by the project.

- The Administrative Services Bureau had the necessary personnel to carry out the data collection and analysis phases of the project.

Department administrators have been pleased with the results achieved with hypercube. In the future, they plan to use either the hypercube version available at National CSS or the Texas A&M version implemented in-house to assess field performance periodically.

Pasadena

The City of Pasadena covers an area of 22.7 square miles and has a population of 112,000. The beat plan in use prior to the hypercube project was implemented in 1975. Under that plan, the area served by the Pasadena Police Department was divided into seven beats. At times, more than one car was assigned to patrol a beat.

Initially, the department planned to use hypercube to examine field performance under the existing plan and alternative plans for each of three watches. In reality, only two watches were examined, no alternative beat configurations were ever presented to field personnel, and no changes were implemented as a result of the hypercube study. Nevertheless, the project consumed approximately seven man-weeks of department staff time, and expenditures for data processing exceeded $1,800, all without producing tangible benefits. There were several reasons for the lack of positive results:

- Neither field nor command personnel perceived a pressing need for change in the patrol plan.
- The department's planning resources are limited. Other duties of the Administrative Services Bureau frequently took precedence over hypercube-related activities.
- Field and command personnel have a mistrust of computers, and even the planner using the system had misgivings about the reliability of the input data being used and the appropriateness of some hypercube assumptions in modelling his department's operations; for example, the department uses a system of priority dispatching and call stacking at the beat level instead of having dispatchers hold and dispatch calls on a first-come, first-served basis.
- The department has no computerized data. As a result, workload data were based on 6,300 incidents sampled from dispatch tickets from May and July 1976. Since no data were available on the time spent on administrative duties such as vehicle maintenance, subjective estimates were used to inflate workloads. This further diminished the confidence the department placed in hypercube performance estimates.

Future use of hypercube in Pasadena is doubtful. The study seemed very much dependent upon data collection assistance provided by TIPPA. Continued use of hypercube would mean continuing the data collection effort and the use of costly outside data processing, neither of which seems likely in view of its limited usefulness to the department.

The experience of the Pasadena Police Department illustrates several principles which may affect the use of hypercube in other departments:

- A hypercube analysis is not likely to be of much value to a department unless it meets an identified need and has the support of field and command personnel.

- Since some required hypercube input data are not routinely collected in many departments, extra time must be spent on collecting data or arriving at subjective estimates.

- The system may not easily model all operations policies, so input data may have to be adjusted and output interpreted to fit local conditions; this may require considerable effort and the services of a planner with some data analysis expertise.

- Departments with a small planning and analysis staff may be unable to allocate sufficient time to work with hypercube. Other high priority tasks may interrupt hypercube operations for a sufficiently long time that the planner must reacquaint himself with hypercube before resuming his analyses.

- Some departments may have no funds budgeted for data collection or data processing. Consequently, hypercube studies may need to be planned months in advance to assure that funds are available.

CHAPTER IV

SETTING UP SHOP FOR USE OF THE HYPERCUBE SYSTEM

A. Introduction

This chapter describes the tasks and procedures involved in preparing to use the hypercube system. Once the decision has been made to proceed with implementation of the system, several preparatory tasks will have to be completed before actual use of the system can begin. Specifically, users will need to:

- obtain and review hypercube documentation and related materials,
- obtain the computer programs and arrange for the necessary training and technical assistance,
- arrange for data processing services and equipment, and
- collect the necessary input data.

Successful completion of these tasks is essential to productive use of the hypercube system. The remaining sections of this chapter deal with each of these preparatory tasks.

B. Obtaining Hypercube Documentation and Materials

This section lists those reports and materials which are felt to be of the greatest potential benefit to persons anticipating use of the hypercube system. The list is divided into two sections: user's manuals, and hypercube theory and applications. Materials classified as user's manuals are those which explain how to use each version of the hypercube software described in Chapter III. The section on hypercube theory and applications lists documents which describe the formulation, assumptions, and uses of the hypercube model; other quantitative models related to the analysis of patrol operations; and case histories of hypercube applications. Appendix B contains the addresses and telephone numbers of the suppliers of the documents listed. Additional information on the hypercube system is contained in the documents referenced at the end of this report.

User's Manuals

1. Instructional Materials for Learning to Use the Hypercube Programs for Analysis of Police Patrol Operations, Richard Kolde, Nelson Heller, William Stenzel, and Allen Gill, St. Louis: The Institute for Public Program Analysis,

July 1977. Available from the National Technical Information Service (NTIS).*

This document is a handbook designed for use in a short training program for police planners learning to use the hypercube system. The material, some of which is in outline form, is intended to be supplemented by class lectures and discussions. Topics covered include: background information on analysis of patrol operations; the advantages, limitations, and assumptions of the model; input data requirements and data collection procedures; step-by-step instructions for operating the programs and interpreting model output; and use of the model to resolve complex patrol policy issues. The materials are designed for use with the TIPPA version of the hypercube system which has been implemented on a commercial time-share system. The version described contains features and commands not found in all versions of the model.

2. Hypercube Queuing Model: User's Manual (R-1688/2-HUD), Richard Larson, Santa Monica: The Rand Corporation, July 1975.

This report is a manual for users of the M.I.T./Rand and M.I.T. advanced versions of the hypercube system. Contents of the volume include descriptions of sample applications of the model, procedures for operating the model on the user's computer system, options available in using the model, the output statistics produced, and the requirements of using the model.

3. Police Officer Deployment System: User's Manual (TEES 1056-76-2), College Station (Texas): Texas A&M University, December 1976.

This report describes the operation and use of the Police Officer Deployment System, of which the hypercube model is one component. For each system component, the report describes the procedures involved in using the programs, preparation of input data, and interpretation of output data.

Hypercube Theory and Applications

1. Field Evaluation of the Hypercube System for the Analysis of Police Patrol Operations: Final Report, Nelson Heller, William Stenzel, Allen Gill and Richard Kolde, St. Louis: The Institute for Public Program Analysis, April 1977. Available from NTIS.

This document discusses the findings of the field test of the hypercube programs conducted by The Institute for Public Program Analysis in cooperation with 10 police departments. The project was funded by the National Science Foundation

---

*Addresses and telephone numbers for the organizations mentioned in this chapter are listed in Appendix B.

(Grant Number APR75-17472). Topics covered include a summary of field test activities, brief case studies of the use of the hypercube system in the 10 participating departments, an assessment of the data processing and other costs associated with use of the system, an assessment of the hypercube software and performance estimates, and a discussion of the institutionalization of the hypercube system and dissemination of hypercube materials.

2. Hypercube Queuing Model: Executive Summary (R-1688/1-HUD), Jan Chaiken, Santa Monica: The Rand Corporation, July 1975.

   This report is a nontechnical description of the hypercube system and is intended to introduce agency administrators and other government officials to the potential uses of the system. The report briefly discusses situations in which use of the hypercube system is appropriate, the underlying theory of the model, use of the system, and the resources required for its use.

3. Urban Public Safety Systems - Volume I, Richard Larson, Lexington (Massachusetts): Lexington Books, 1977.

   This volume contains an edited accumulation of earlier publications on the hypercube model and implementation experiences in several police departments. Approximately half of the volume is devoted to the hypercube system. Topics covered include the underlying motivation for the hypercube model, the basic elements of its structure, the assumptions used in the model, and illustrative examples of the use of hypercube in urban police departments.

4. Implementing the Hypercube Queuing Model in the New Haven Department of Police Services: A Case Study in Technology Transfer (R-1566/6-HUD), Kenneth Chelst, Santa Monica: The Rand Corporation, July 1975.

   This report details the implementation of the hypercube model in New Haven, Connecticut, with emphasis upon the process of collecting the data required by the model, the analysis of the model's output, and how various policy issues can be analyzed with the model. Although the model was implemented in New Haven and police personnel were trained to use it, the department decided not to use hypercube to design revised patrol beats. A concluding section of the report discusses the issues involved in this decision.

5. "A Hypercube Queuing Model for Facility Location and Redistricting in Urban Emergency Services," Richard Larson, Computers and Operations Research, Vol. 1, No. 1 (March 1974), pp. 67-95. (Also available from the Rand Corporation as R-1238-HUD, March 1973.)

   Quite technical in nature, this paper describes the mathematical development of the exact hypercube model, including the computational algorithms embodied in the model. There is also a review of recent literature pertaining to urban facility location and redistricting, showing weaknesses in previous methods which the hypercube model attempts to overcome.

6. Urban Police Patrol Analysis, Richard Larson, Cambridge, (Massachusetts): The M.I.T. Press, 1972.

This book describes a wide range of quantitative models that bear on the analysis of patrol operations. Included are models of patrol and response functions that estimate the effectiveness of user-specified patrol allocation plans and a simulation model to predict the consequences of a variety of complex patrol procedures. Introductory chapters discuss the problems and issues related to patrol analysis, and six technical chapters detail the analytical models.

C. Obtaining the Computer Programs, Training, and Technical Assistance

In a previous chapter the four currently available versions of the hypercube software were described: M.I.T./Rand, M.I.T., TIPPA, and Texas A&M (see Table 2-1 for a summary of their characteristics). This section describes how to obtain the computer programs, related training, and technical assistance. Since some of the suppliers offer both software and services the following discussion is organized by source. Inquiries regarding the cost and current availability of the materials and services identified may be directed to the suppliers listed; their addresses and telephone numbers are listed in Appendix B.

The following subsection deals with hypercube resources which are presently available; the second outlines resources which are likely to be available in the near future.

Currently Available Software, Training, and Technical Assistance

1. The Institute for Public Program Analysis

Copies of all four versions of the hypercube software can be obtained from The Institute for Public Program Analysis (TIPPA). Related software facilitating the use of the TIPPA hypercube system on National CSS (NCSS), an internationally accessible, commercial time-share data processing system, is also available.

TIPPA provides training for new hypercube users during a periodic one-week seminar entitled "Computerized Police Patrol Management Using the Hypercube Programs." This seminar features a thorough discussion of police patrol allocation, use of interactive and non-interactive versions of the hypercube software, and "hands-on" experience in using a data terminal and operating the software implemented on the National NCSS time-share system.

Technical assistance is available in the areas of "setting up shop," data collection, using the software, and interpretation and analysis of hypercube output.

TIPPA also provides training and technical assistance in the use of other computer-based police field operations models--notably patrol car allocation and manpower scheduling.

2. Massachusetts Institute of Technology

Copies of all four versions of the hypercube software are also available from M.I.T., which offers only limited technical assistance.

M.I.T. annually offers a one-week seminar entitled, "Analysis of Urban Service Systems," in which one day is devoted to the hypercube system.

3. The Rand Corporation

Copies of the M.I.T./Rand and Texas A&M versions of the hypercube software, as well as Rand's Patrol Car Allocation Model (PCAM), may be obtained from the Rand Corporation. No technical assistance or training is offered.

4. Texas A&M University

Copies of the Patrol Officer Deployment System (PODS) software package are available from the University's Center for Urban Programs. These computer programs, written in the COBOL language, were developed through a grant from the Criminal Justice Division, Office of the Governor of Texas. In addition to the Texas A&M version of the hypercube software, the package contains other programs which automatically modify an initial district design in order to balance beat workloads or travel times, forecast the number of calls for service of a specified type during future watches in each district, and produce maps on a line printer showing district boundaries. Only limited technical assistance is available. No training is offered.

5. National Technical Information Service (NTIS)

Copies of the M.I.T./Rand version of the hypercube software are available from NTIS (order number PB 259 882). Related documentation is automatically supplied with each order at no extra charge. No technical assistance or training is offered.

6. Dr. Ernst Nilsson, Stockholm, Sweden

Dr. Nilsson has developed an adaptation of the M.I.T./Rand version of the hypercube software for use by police departments in less urbanized areas, many of which exist in Sweden. His software, written in the FORTRAN programming language, produces many of the performance statistics generated by the original hypercube system. Technical assistance and training are available.

7. DeKalb County, Georgia, Police Department

The DeKalb County Police Department has developed a computer-based mapping system. While independent of the hypercube software, the system enables hypercube users to produce maps on a line printer showing such information as preventive patrol distributions among reporting areas. Neither training nor technical assistance is available.

8. Management Consulting Firms

The following management consulting firms have copies of various versions of the hypercube software; in the past, they have provided technical assistance in their use and in the evaluation and design of patrol policies.

- Urban Sciences, Inc. (Wellesley, Massachusetts),
- Public Management Services, Inc. (McLean, Virginia), and
- Public Systems Evaluation, Inc. (Cambridge, Massachusetts).

While no formal classroom training is offered by these firms, in some instances they have trained individual clients to operate the software.

9. Traffic Institute, Northwestern University

An introduction to the hypercube system is included in the curriculum of three police management training courses offered annually by the Traffic Institute: "Traffic Police Administration Training Program," "Principles of Police Management," and "Law Enforcement Planning Officers Seminar." Neither technical assistance nor copies of the software are available from the Traffic Institute.

10. International Association of Chiefs of Police (IACP)

Some of the police management training programs offered by IACP present an introduction to computer-based police resource allocation planning tools, including coverage of hypercube.

Future Hypercube Resources

Software. Any future versions of the hypercube software

are likely to be available from and announced by NTIS. In addition to distribution by the sources listed above, current versions may be distributed in the future by public technology software exchanges and by some local or regional criminal justice information systems. Information on public technology organizations may be obtained from the Division of Intergovernmental Science and Public Technology of the National Science Foundation (NSF).

Training. It is likely that training concerning hypercube will be added to in-service training programs offered by some university-based, regional, and private law enforcement educational institutions. Announcements of such programs are normally made through law enforcement periodicals and newsletters such as Training Aids Digest, Law Enforcement News, Crime Control Digest, and the National Criminal Justice Reference Service SNI system.

Technical assistance. Future sources of technical assistance probably will include public technology organizations and LEAA-funded technical assistance services. For information on the latter the LEAA Office of Regional Operations should be contacted.

Information on other sources of technical assistance may be available from the National Clearinghouse for Criminal Justice Information Systems (SEARCH Group, Inc.) and the National Referral Center of the Library of Congress.

Documentation. Most future publications concerning hypercube should be available through NTIS and the National Criminal Justice Reference Service.

D. Arranging for Data Processing Services and Equipment

This section discusses procedures for obtaining data processing services and equipment required to use the hypercube system. The procedures described will be of most interest to police departments planning to use a commercial, rather than an in-house, data processing system, or to departments planning to access the hypercube system via a data terminal connected to a computer by telephone.

The main task in arranging for data processing services and equipment is to identify and select the most suitable vendor from among the numerous companies which market such services and equipment. Tables 4-1 and 4-2 identify some of these companies. Others can be identified by consulting data processing publications or the telephone directory.

The requirements of the data processing system are summarized in Chapter III. These include support of PL/I or COBOL programming language, sufficient core storage capacity, and, if possible, local accessibility. Other factors that may be important in choosing a vendor are:

Table 4-1

PARTIAL LIST OF COMMERCIAL VENDORS OF DATA PROCESSING SERVICES[a]

Boeing Computer Services, Inc. (McLean, Virginia)
Computer Network Corporation (Washington, D.C.)
Comshare, Inc. (Ann Arbor, Michigan)
Data Resources, Inc. (Lexington, Massachusetts)

General Electric, Inc. (Bethesda, Maryland)
GTE Data Services, Inc. (Tampa, Florida)
Honeywell Information Services, Inc. (Minneapolis, Minnesota)
Information Systems Design, Inc. (Santa Clara, California)
Interactive Data Corporation (Waltham, Massachusetts)

Martin Marietta Data Systems (Towson, Maryland)
McDonnell Douglas Automation Company (St. Louis, Missouri)
National CSS, Inc. (Norwalk, Connecticut)
PRC Computer Center, Inc. (McLean, Virginia)
Proprietary Computer Systems, Inc. (Van Nuys, California)

Rapidata, Inc. (Fairfield, New Jersey)
Remote Computing Corporation (Palo Alto, California)
Scientific Time Sharing Corporation (Bethesda, Maryland)
The Service Bureau Company (Greenwich, Connecticut)
A. O. Smith Corporation (New Berlin, Wisconsin)

Tymshare, Inc. (Cupertino, California)
United Computing Systems, Inc. (Kansas City, Missouri)
University Computing Company (Dallas, Texas)

[a]The location of each vendor's corporate headquarters is listed. Information on regional offices can be obtained by contacting the headquarters.

Table 4-2

PARTIAL LIST OF COMMERCIAL VENDORS OF TELETYPEWRITER-DATA TERMINALS[a]

Acrodyne Data Devices, Inc. (Union City, New Jersey)
Anderson Jacobson, Inc. (Sunnyvale, California)
Carterfone Communications Corporation (Dallas, Texas)
Centronics Data Computer Corporation (Hudson, New Hampshire)
Computer Devices, Inc. (Burlington, Massachusetts)

Computer Transceiver Systems, Inc. (Paramus, New Jersey)
Data Access Systems, Inc. (Mountain Lake, New Jersey)
Dataproducts Corporation (Stamford, Connecticut)
Data Terminals and Communications (San Jose, California)
Digital Equipment Corporation (Maynard, Massachusetts)

Gen-Com Systems, Inc. (Los Angeles, California)
General Electric Company (Waynesboro, Virginia)
Harris Communications Systems, Inc. (Dallas, Texas)
International Business Machines Corporation (White Plains, New York)
Leasco Data Communications Corporation (Germantown, Maryland)

Memorex Corporation (Santa Clara, California)
NCR Corporation (Dayton, Ohio)
Olivetti (New York, New York)
Randall Data Systems (Torrance, California)
RCA Service Company (Camden, New Jersey)

Teletype Corporation (Skokie, Illinois)
Terminal Communications (Raleigh, North Carolina)
Texas Instruments (Stafford, Texas)
Trendata Computer Systems (Sunnyvale, California)
Univac (Blue Bell, Pennsylvania)

Western Union Data Services Company (Mahwah, New Jersey)

[a]The location of each vendor's corporate headquarters is listed. Information on regional offices can be obtained by contacting the headquarters.

- availability and quality of documentation, training, and technical assistance in the use of the data processing system;

- types of data terminals supported;*

- system reliability; and

- usage costs such as monthly minimums, and the charges for terminal connect time, data storage, central processor time, and input/output operations. Unfortunately, comparison of these charges between suppliers is difficult because of differing procedures used to compute charges.

The information needed to assess these factors can be obtained from the companies' marketing representatives.

Once a data processing vendor has been selected, an account number, access to the system, user's manuals, etc., can be obtained by sending a written request for services to the vendor's business office, signing a contract, and, in some cases, supplying credit information. This process can usually be completed in one to two weeks, whereupon a tape copy of the hypercube software can be sent to the vendor's central site computer center, and subsequently accessed from the user's terminal. Information on this procedure, and assistance in implementing the hypercube system, can be obtained from the vendor's technical representatives.

Factors that should be considered in selecting a supplier for terminal equipment include the following:

- the terms of the rental agreement, including monthly rental fees and the shortest lease time permitted;

- availability and cost of equipment service and supplies;

- incidental costs such as shipping and installation charges;

- peripheral equipment required;

- printer characteristics such as type of print mechanism (thermal or impact), number of print positions per line, print speed (i.e., number of characters that can be printed per second),

---

*Not all commercial data processing systems support all types of data terminals. Consequently, the system selected should support in-house terminal equipment; or alternatively, arrangements for such equipment should be made only after the data processing supplier has been identified.

character set used, and keyboard layout;*

- terminal size and portability; and

- compatibility with requirements of the data processing system to be used.

This information can be obtained and equipment demonstrations can be arranged by contacting the suppliers' sales representatives.

Orders for service and equipment are placed by signing a rental agreement and, in some cases, making advance payment of the charge for the minimum length lease. Depending on the availability of equipment, delivery of a terminal usually takes from one to three months.

E. Collecting Data for the Hypercube System

The hypercube computer programs require considerable information about the geography and workload distribution of a region, the deployment practices used for the patrol force, the rules and guidelines used by dispatchers to select patrol units for assignments, and the service time and travel speeds of patrol units. Very few police departments routinely collect all of the input data required for the hypercube programs. As a result, most departments planning to use the hypercube system will find it necessary to initiate some data collection activities to supplement input data obtainable from existing department records. Depending on the data resources, these data collection activities may take considerable personnel time.

This section reviews both the data items required and the data planning activities that should precede and accompany data collection activities.

Data Planning

Data planning should include the following major activities:

- review of hypercube input data items by key project personnel,

- determination of the number of distinct beat plans to be designed,

---

*Printer characteristics need not be an important selection criterion for hypercube users, although the output of some versions of hypercube will be more readable when listed on terminals with a line capacity of at least 120 characters. A print speed of at least 30 characters per second is recommended if large amounts of output are to be listed on the terminal. The type of print mechanism will affect print quality and the noise level of the terminal.

- survey of existing department records and identification of data collection activities required, and

- preparation and coordination of data collection activities.

Each of these activities is discussed below.

Review of hypercube input data items. Personnel directly responsible for data collection activities should familiarize themselves with each of the input data items required for the hypercube system. A thorough understanding of each data item, its use in the hypercube program, the units in which it is measured, and the required accuracy of the inputs are basic to all elements of the data planning process, from surveying existing department records to planning efficient data collection procedures.

Determining how many beat plans will be designed. The number of distinct beat plans to be designed depends on the number of regions in a city and the number of different plans to be used in each region. Distinct beat plans are usually designed for each region. Within a region, different plans may be used for different hours of the day, such as for each watch, and for different days of the week--some departments use different beat plans on Fridays and Saturdays to accommodate increased numbers of patrol units.

Input data collected for the design of each beat plan should be based exclusively on the geographic region and time periods for which each plan will be used. For example, if plan A is intended for use on the afternoon watch on Fridays and Saturdays in Region 1, the input data used to design plan A should be based exclusively on data collected from Friday and Saturday afternoon tours in Region 1.

The number of distinct beat plans to be designed influences the data planning process in two ways:

- as the number of plans increases, the amount of data to be collected usually increases; and

- data should be collected so that the appropriate data base for each beat plan to be designed can be readily obtained.

Survey of department records. An accurate appraisal of the specific input data items not readily available in department records, and realistic estimates of the collection effort required to obtain them may influence the decision of a department as to whether it can profitably use the hypercube system. Once a decision to use hypercube has been made, the survey of department records can be a valuable resource in designing efficient data collection procedures.

The survey should provide the following information for each data item:

- Does the department currently capture the data item? Where are the data kept? What medium is used for storing the data (i.e., paper, punched cards card, microfilm, magnetic tape, etc.)?

- How much data exist and what period of time do they cover?

- Who records the data? What units of measurement are used? What rules or guidelines are used by the data recorders? Have these rules or guidelines been changed recently? What happens to incomplete or erroneous data?

- Who uses the data? Why are they collected?

- Are the data summarized in department management reports? Who produces these reports? What rules or guidelines are used to produce them? What vital data are excluded, and why? How is each aggregate statistic in the management report computed?

- Can the data be cummarized and broken down by the regions and time periods covered by each beat plan to be designed?

- How complete and reliable are the data? Are the data verified? Are the users of the data aware of data errors? Are the data accurate enough for use in the hypercube system?

- What data collection activities will be necessary to obtain accurate estimates (e.g., sampling from paper sheets or dispatch records, processing key-punch cards, or observing field or dispatching operations)? To what extent will these activities interfere with any other department activities? How cooperative are the persons directly responsible for the records or operations involved?

- What data collection efforts in terms of man-hours will be required to obtain each needed item?

Planning data collection activities. Careful design and coordination are important elements in the process of collecting accurate and useful input data with minimum effort and disruption of other department activities. Key data collection activities include:

- the determination of an appropriate sample size for each data item, and the time span to be covered by the sample: should the sample cover one week, one month, or one year?;

- the design of collection procedures for obtaining representative samples from the time period selected for each item;

- the identification of specific times and locations where samples can be drawn and data items can be recorded; this is particularly important if the data records cannot be moved;

- the design of collection forms which facilitate both the coding of each data item from source documents and the aggregation of the data into summary statistics usable in the hypercube program; if the coded data will be processed by computer analysis, the form should also be designed to facilitate keypunching;

- the specification of a set of rules to be used by personnel coding the data items from department records; these rules should include a procedure for dealing with coding problems not specifically covered by any of the other rules;

- the selection and training of the data coders; it is often useful to review the initial work of each coder to identify and resolve unexpected problems; and

- the coordination of keypunching, programming, and data processing services if some data items will be processed by computer; the volume of coded data may be too large for manual calculations, or the data items may be stored on cards, tape, or disk.

<u>Input Data for the Hypercube System</u>

The input data required for the hypercube programs fall into five categories: geographic, workload, deployment, dispatching, and operations. The hypercube model assumes that the entire region of interest has been partitioned into small non-overlapping reporting areas (RA) which can be used to describe the geographic area of each beat and the distribution of work throughout the entire region. The properties of these reporting areas and a description of the input data items in each of the five data categories are discussed below.

<u>Reporting areas</u>. To use the hypercube model to estimate the performance statistics of a proposed beat plan, the entire region of interest must be partitioned into small geographic areas. These reporting areas are the smallest geographic

areas for which workload data are collected.* Reporting areas are used in two ways by the hypercube model:

- to describe the geographic distribution of workload for the entire region; and

- to define the geographic area covered by each beat.

As an example, the reporting area structure for the Ninth Police District in the City of St. Louis is shown in Figure 4-1.** The district is divided into 36 reporting areas which are used to describe the distribution of work throughout the district, and to define the geographic area of each beat.

Although not required by the hypercube system, ideally the set of reporting areas defined for a region should:

- cover the entire region of interest;

- be non-overlapping;

- be small enough so that each beat covers from 6 to 12 reporting areas;

- be compactly shaped--shaped more like circles than elongated boxes;

- cover approximately the same area;

- have a uniform workload level, although the workload levels can be expected to vary considerably from one reporting area to another; and

- possess boundaries which coincide with major thoroughfares, limited access highways, and natural barriers.

<u>Geographic data</u>. The geographic data required for the hypercube programs include the following:

- the number of reporting areas in the region;

- a unique numeric label for each reporting area;

- the geographic center of each reporting area defined by the x,y distances in miles from the center of the reporting area to an arbitrary reference point. The same reference point, usually placed on the perimeter of the region, must be used to define the geographic center of all reporting areas; the

---

*Reporting areas are also called atoms, zones, grids, and beat blocks.

**Since patrol units in each police district in St. Louis operate almost exclusively within their assigned district, each district would be treated as a separate region for a hypercube analysis.

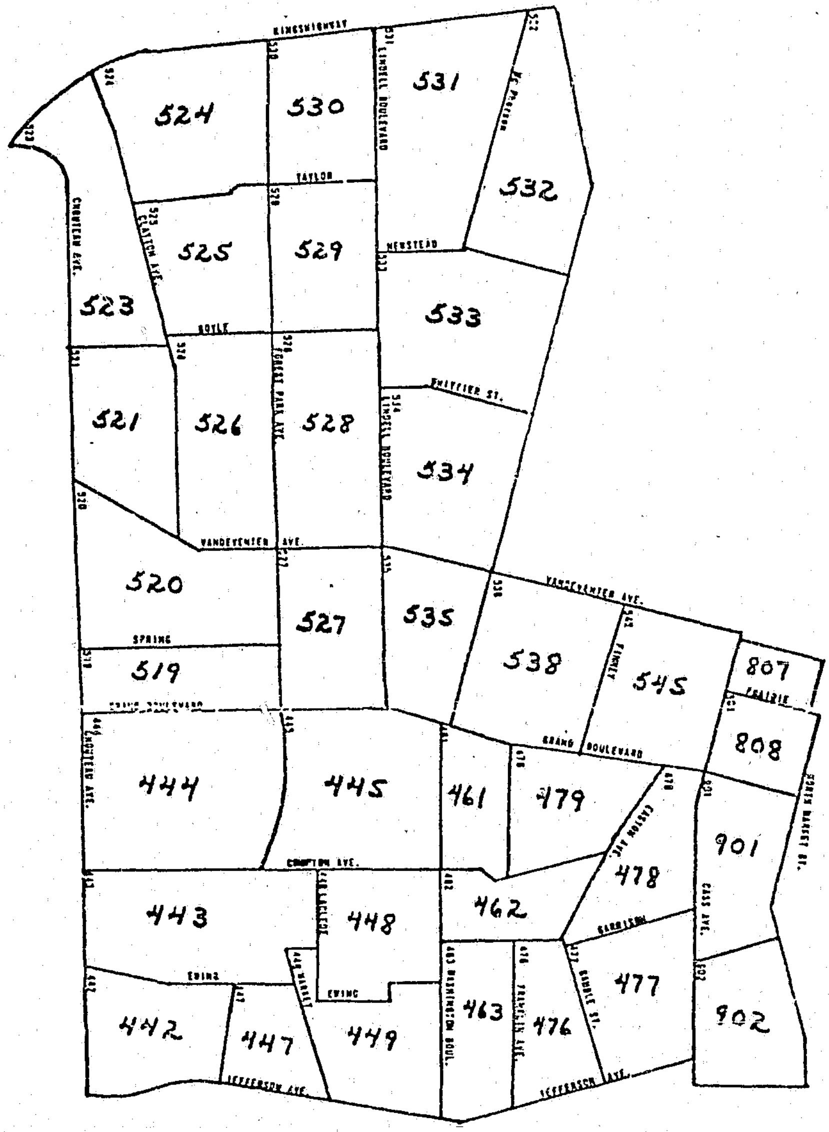


Figure 4-1

REPORTING AREAS FOR THE NINTH POLICE DISTRICT IN THE CITY OF ST. LOUIS coordinates are used in the hypercube programs to calculate the distance between each pair of reporting areas; and

- the area of each reporting area in square miles. These areas are used to calculate intra-reporting area travel distances.

These geographic data items are collected once for each region and remain constant for all beat configurations designed for that region.

Workload data. The hypercube model assumes that, for each tour of duty, all time spent by a patrol unit can be partitioned into only two categories: unavailable time (i.e., time when a unit is occupied and therefore not available for other assignments), and available time (i.e., time when a unit is on preventive patrol and is available for work assignment). Using these definitions, the hypercube model defines unit workload as the fraction of time during each tour that a unit is unavailable.

The hypercube model further assumes that unit unavailability is caused exclusively by dispatched work assignments generated by calls for service (CFS). This assumption of a single source of patrol work does not explicitly recognize that considerable amounts of unavailable time can be generated by non-CFS activities such as self-initiated work and administrative duties. Time spent on these activities can only be represented in the hypercube model by adjusting input CFS data to adequately reflect all unit unavailable time.* In the remainder of this section, it is assumed that workload data have been adjusted for non-CFS activities. The hypercube model requires two workload data items:

- Relative workload in each reporting area is used to describe the geographic distribution of work throughout the region; the workload for each reporting area is usually based on the number of CFS incidents reported over a selected time span.

- Absolute volume of workload for the region, expressed in number of calls per hour, is used to indicate the total amount of work (unavailable time) that the patrol force must handle each hour for the entire region. This rate is usually estimated by counting the number of CFS incidents for several days or weeks and dividing

---

*The procedures for adjusting hypercube workload data to accommodate non-CFS activities are described in Chapter 10 of Instructional Materials for Learning to Use the Hypercube Programs for Analysis of Police Patrol Operations.

by the total number of hours in the time span.

It is important to note that both data items should correspond to the time periods (i.e., hours of the day and days of the week) covered by each beat plan to be designed. As an example, if a department with a three-watch operation plans to design two beat plans for each watch, one plan for use on Fridays and Saturdays, and the second for use on Sundays through Thursdays, six sets of workload data must be collected which correspond to the time periods covered by each of the six beat plans.

Deployment data. These input data items are used to describe the size of the patrol force, the beat structure of the region, and the policy used to govern preventive patrol. These data items include:

- the number of patrol units;
- the reporting areas included in the beat covered by each patrol unit - the geographic areas covered by two beats can be completely overlapping (equivalent to two units assigned to the same geographic area), partially overlapping (two beats which share some but not all reporting areas), or completely non-overlapping; and
- the preventive patrol policy - the relative amount of time each patrol unit spends in each reporting area in its beat while it is on preventive patrol.

Dispatch policy data. Dispatch policy refers to the set of rules and procedures used by dispatchers to determine which unit should be selected to handle each call. The hypercube model assumes that dispatchers use a fixed preference list to select the most appropriate unit for each call.* As each call is received, the dispatcher uses his knowledge of the location of the call and each unit to select the most appropriate unit by beginning at the top of the list and dispatching the first available unit.

In the hypercube model, dispatching preference lists are constructed which are based on the travel distance between the call location and each patrol unit in the field. Different dispatch policies in the model are based on how well the dispatcher knows the geographic location of each call and patrol unit, what policy is used if a non-beat unit is closer to an incident than the beat unit, and what procedures are followed if all patrol units are unavailable. The data items

---

*The user can specify a special dispatching policy in which the closest available unit is always dispatched.

and the options available with each are:

- Should the beat unit, if available, always be selected for every call in its beat? The beat-unit-first option should be used by departments which have a policy of assigning the beat unit, if available, to every call in its own beat. This option is equivalent to placing the beat unit at the top of the dispatch preference list for each reporting area in its beat. If the beat-unit-first option is not selected, the preference list for each reporting area is determined on the basis of travel time alone. This is equivalent to a policy of always selecting the closest available unit regardless of beat responsibilities.

- Are all CFS incidents handled by the patrol force? This data item deals with the situation in which the patrol force is saturated--i.e., when every unit on the preference list is unavailable. The queuing option assumes that when the patrol force is saturated, the dispatcher holds (queues) the call and assigns it to the first unit available. This option should be used for departments in which all work in a region is handled by the patrol force. If the queuing option is not selected the hypercube model assumes that if a call arrives when all patrol units are unavailable, the dispatcher will assign the call to a non-patrol unit. The no-queuing option is equivalent to adding an unlimited number of backup units to the bottom of each preference list.

- How accurately does the dispatcher know the location of each call and each available unit? The dispatching preference lists constructed by the hypercube model depend on the accuracy with which the dispatcher knows the location of the call and each available unit. The hypercube model has five preprogrammed options which reflect the dispatcher's knowledge about call and unit locations.*

Although only a limited number of options are available in the hypercube model to describe the dispatch policy, data collection efforts to determine which option is most appropriate can be a difficult data collection task. Although many departments do have established policies governing dispatch selection procedures, few departments routinely investigate how well these policies are followed. Studies

---

* See Chapter V of Instructional Materials for Learning to Use the Hypercube Programs for Analysis of Police Patrol Operations.

in some departments have revealed substantial differences between established department policy and actual dispatch procedures. Some departments may find that none of the dispatching policy options available accurately reflects their dispatch procedures. For these departments, dispatch options must be selected which most closely approximate department operations.

Operations data. The hypercube model requires estimates for two parameters based on field operations. These are:

- average service time - the average number of minutes each unit spends servicing a call; this time includes travel time, on-scene time, and any administrative follow-up time; and

- average travel speed - the average speed, in miles per hour, of units responding to a call; accurate estimates of travel speed are often very difficult to obtain.

APPENDIX A

TABLES OF DATA PROCESSING COSTS AND STORAGE REQUIREMENTS

Table A-1

CORE STORAGE REQUIRED TO USE
THE APPROXIMATE HYPERCUBE MODEL[a]

NUMBER OF REPORTING AREAS	NUMBER OF UNITS 3	6	9	12	15	18	21	24	27	30	33
25	240	243	245	248	251	253	256	259	261	264	266
50	251	256	260	265	270	275	280	285	289	294	299
75	266	273	280	287	295	302	309	316	323	330	337
100	287	296	305	315	324	333	342	352	361	370	379
125	312	324	335	347	358	369	381	392	404	415	427
150	343	356	370	383	397	411	424	438	452	465	479
175	378	394	409	425	441	457	473	489	504	520	536
200	418	436	454	472	490	508	526	544	562	580	598
225	463	483	503	523	544	564	584	604	624	645	665
250	512	535	557	580	602	625	647	669	692	714	737
275	567	592	616	641	666	690	715	739	764	789	813
300	627	654	680	707	734	7[illegible]1	788	814	841	868	895

[a]Storage requirements are specified in units of K-bytes where one K-byte = 1024 bytes. For example, to use the hypercube system to analyze 12 units over 200 reporting areas requires 472 K-bytes (483,328 bytes) of core storage.

Table A-2

CORE STORAGE REQUIRED TO USE THE EXACT HYPERCUBE MODEL WITH NON-AVL DISPATCHING[a]

NUMBER OF REPORTING AREAS	NUMBER OF UNITS 2	3	4	5	6	7	8	9	10	11	12	13	14	15
25	239	240	241	243	244	247	253	263	284	327	416	601	986	1787
50	249	251	253	255	257	261	267	278	300	344	433	619	1004	1806
75	264	267	269	272	275	280	287	298	321	365	455	642	1028	1831
100	284	287	290	294	298	303	311	323	346	391	483	670	1057	1860
125	309	312	316	321	326	331	340	353	377	423	515	702	1090	1894
150	338	343	347	352	358	365	374	388	412	459	551	740	1128	1933
175	372	378	383	389	395	403	413	427	453	500	593	782	1172	1977
200	412	418	424	431	438	446	456	472	498	546	640	830	1220	2026
225	456	463	470	477	485	494	505	521	548	597	691	882	1273	2080
250	505	513	520	528	537	546	558	575	603	652	748	939	1331	2138
275	559	567	576	584	594	604	617	634	663	713	809	1001	1393	2202
300	618	627	636	645	655	666	680	698	727	778	875	1068	1461	2270

[a]Storage requirements are specified in units of K-bytes where one K-byte = 1024 bytes. For example, to use the hypercube system to analyze 6 units over 100 reporting areas requires 298 K-bytes (305,152 bytes) of core storage.

Table A-3

ESTIMATED COST OF CREATING AN INPUT FILE
DESCRIBING REGION GEOGRAPHY AND WORKLOAD[a]

NUMBER OF REPORTING AREAS

50	75	100	125	150	175	200	225	250	275	300
$10.00	13.00	17.00	20.00	23.00	26.00	29.00	32.00	35.00	38.00	41.00

[a]For example, the cost of creating a region file with 125 reporting areas is approximately $20.00.

Table A-4

ESTIMATED COST OF MODIFYING AN EXISTING INPUT FILE
DESCRIBING REGION GEOGRAPHY AND WORKLOAD[a]

NUMBER OF REPORTING AREAS

50	75	100	125	150	175	200	225	250	275	300
$9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	18.00	10.00	20.00

[a]For example, the cost of modifying an existing region file with 125 reporting areas is approximately $12.00.

Table A-5

ESTIMATED COST OF ONE ON-LINE HYPERCUBE ITERATION
(ONE WORKLOAD LEVEL)[a]

NUMBER OF REPORTING AREAS	NUMBER OF UNITS: 4	7	10	13	16	19	22	25	28	31	34
50	$10.00	15.00	19.00	23.00	28.00	32.00	37.00	41.00	46.00	50.00	55.00
75	13.00	17.00	21.00	26.00	30.00	35.00	39.00	44.00	48.00	53.00	57.00
100	15.00	20.00	24.00	28.00	33.00	37.00	42.00	46.00	51.00	55.00	59.00
125	18.00	22.00	26.00	31.00	35.00	40.00	44.00	49.00	53.00	58.00	62.00
150	20.00	24.00	29.00	33.00	38.00	42.00	47.00	51.00	56.00	60.00	64.00
175	23.00	27.00	31.00	36.00	40.00	45.00	49.00	54.00	58.00	62.00	67.00
200	25.00	29.00	34.00	38.00	43.00	47.00	52.00	56.00	61.00	65.00	69.00
225	27.00	32.00	36.00	41.00	45.00	50.00	54.00	59.00	63.00	67.00	72.00
250	30.00	34.00	39.00	43.00	48.00	52.00	57.00	61.00	65.00	70.00	74.00
275	32.00	37.00	41.00	46.00	50.00	55.00	59.00	63.00	68.00	72.00	77.00
300	35.00	39.00	44.00	48.00	53.00	57.00	62.00	66.00	70.00	75.00	79.00

[a]For example, the cost of one on-line hypercube iteration for a region with 150 reporting areas and 10 units is approximately $29.00.

Table A-6

ESTIMATED COST OF ONE BATCH HYPERCUBE ITERATION (ONE WORKLOAD LEVEL)[a]

NUMBER OF REPORTING AREAS	NUMBER OF UNITS 4	7	10	13	16	19	22	25	28	31	34
50	$10.00	13.00	16.00	19.00	22.00	25.00	27.00	30.00	33.00	36.00	39.00
75	11.00	14.00	17.00	20.00	23.00	26.00	28.00	31.00	34.00	37.00	40.00
100	12.00	15.00	18.00	21.00	24.00	27.00	30.00	32.00	35.00	38.00	41.00
125	13.00	16.00	19.00	22.00	25.00	28.00	31.00	33.00	36.00	39.00	42.00
150	14.00	17.00	20.00	23.00	26.00	29.00	32.00	35.00	37.00	40.00	43.00
175	15.00	18.00	21.00	24.00	27.00	30.00	33.00	36.00	38.00	41.00	44.00
200	16.00	19.00	22.00	25.00	28.00	31.00	34.00	37.00	39.00	42.00	45.00
225	18.00	20.00	23.00	26.00	29.00	32.00	35.00	38.00	41.00	43.00	46.00
250	19.00	21.00	24.00	27.00	30.00	33.00	36.00	39.00	42.00	44.00	47.00
275	20.00	22.00	25.00	28.00	31.00	34.00	37.00	40.00	43.00	46.00	48.00
300	21.00	24.00	26.00	29.00	32.00	35.00	38.00	41.00	44.00	47.00	49.00

[a]For example, the cost of one batch hypercube iteration for a region with 150 reporting areas and 10 units is approximately $20.00.

APPENDIX B

SUPPLIERS OF HYPERCUBE PROGRAMS, MATERIALS, TRAINING, AND TECHNICAL ASSISTANCE

CONTINUED

1 OF 2

Listed below are the names, addresses, and telephone numbers for suppliers of hypercube programs, materials, training, and technical assistance. Suppliers which provide each of these items are discussed in Chapter IV.

1. The Institute for Public Program Analysis
   230 South Bemiston Avenue, Suite 914
   St. Louis, Missouri 63105
   Attention: Dr. Nelson Heller
   (314) 862-8272

2. Massachusetts Institute of Technology
   Operations Research Center
   Room 24-215
   Cambridge, Massachusetts 02139
   Attention: Dr. Richard Larson
   (617) 253-3601

3. The Rand Corporation
   1700 Main Street
   Santa Monica, California 90406
   Attention: Dr. Jan Chaiken
   (213) 393-0411

4. Texas A & M University
   Center for Urban Programs
   Department of Industrial Engineering
   College Station, Texas 77843
   Attention: Dr. Roger Elliot
   (713) 845-5531

5. National Technical Information Service (NTIS)
   Computer Products Division
   Department of Commerce
   5285 Port Royal Road
   Springfield, Virginia 22161
   (703) 321-8500

6. Dr. Ernst Nilsson
   T.O.S.
   Baggensgatan 19
   111 31 Stockholm, Sweden

7. DeKalb County Police Department
Data Processing Department
Court House Square
Decatur, Georgia 30030
Attention: Mr. William Gaston
(404) 294-2588

8. Urban Sciences, Inc.
177 Worchester Street
Wellesley, Massachusetts 02181
Attention: Mr. Lloyd Howells
(617) 237-5410

9. Public Management Services, Inc.
7600 Old Springhouse Road
McLean, Virginia 22101
Attention: Dr. Thomas McEwen
(703) 893-1830

10. Public Systems Evaluation, Inc.
929 Massachusetts Avenue
Cambridge, Massachusetts 02139
Attention: Dr. Richard Larson
(617) 547-7620

11. The Traffic Institute
Northwestern University
405 Church Street
Evanston, Illinois 60204
Attention: Mr. Russell Arend
(312) 492-5222

12. International Association of Chiefs of Police (IACP)
Technical Research Services Division
11 Firstfield Road
Gaithersburg, Maryland 20760
Attention: Mr. Sampson Chang
(301) 948-0922

13. Division of Intergovernmental Science & Public Technolo
National Science Foundation
1800 G. Street N. W.
Washington, D. C. 20550
Attention: Director
(202) 634-7996

14. Office of Regional Operations
Law Enforcement Assistance Administration
633 Indiana Avenue, N. W.
Washington, D. C. 20531
Attention: Mr. Robert Heck
(202) 376-3944

15. National Clearinghouse for Criminal Justice Information Systems
SEARCH Group, Inc.
1620 35th Avenue
Sacramento, California 95822
Attention: Mr. William Connor
(916) 392-2550

16. National Referral Center
Science and Technology Division
Library of Congress
Washington, D. C. 20540

APPENDIX C

IMPLEMENTING REVISED BEATS

After the hypercube system has been used to design a new patrol beat plan, careful consideration should be given to the process of putting the plan into effect. This implementation process may be quite simple in relatively small departments, in those that change their beat plans on a regular basis, and those making few other changes in patrol allocation. However, the process may be more difficult in large departments, in those that have not adjusted their beat plans for several years, and in those making major allocation changes.

This appendix offers guidelines--presented as a series of steps or tasks to be performed--for the successful implementation of new beat plans. The tasks are not necessarily sequential; some can be performed simultaneously or in a different order than listed, while some may be unnecessary in some departments.

A. Reviewing the Potential Impact of Proposed Changes Upon Patrol Allocation and Other Department Functions

As described in Chapter I, beat design is only one part of a total patrol allocation plan. Beat design changes may require adjustments in other aspects of patrol allocation, and these should be considered in planning for the implementation of revised beat configurations. When designing new beats, the need for changes in other aspects of patrol allocation should be reviewed, since the impact upon these other areas may be a factor in selecting a new beat plan from several alternative plans. The implementation of new beat plans may be resisted by field personnel because of changes in patrol allocation associated with the new plan.

Allocation changes which may accompany the implementation of new beat configurations may result in a need for:

- changes in the geographical or temporal distribution of patrol manpower to balance workloads among different regions, times of the day, and days of the week;
- revision of supervisory areas;
- new work schedules for officers and supervisors to provide the required number of men on duty when needed;
- reexamination of whether beat integrity and unity of command are provided for--i.e., assignment of officers to the same beats and supervisors each time they are on duty;
- revision of dispatch policies (hypercube can be used to consider such changes beforehand); and

- revision of computer-aided dispatching systems.

Other aspects of department operation may also be affected by beat plan changes. It should be understood that:

- Once beat boundaries are changed, beat statistics from previous years cannot be compared with data compiled by beat under the new plan.
- Patrol officers or clerks assigning beat numbers to incident addresses will need to be trained to use the new numbers, if these have been changed.
- Special police community relations and crime prevention programs may be affected by the new beat plan.
- The number of vehicles available must be sufficient to meet the need during periods of peak manning.
- Increasing the number of units fielded during busy watches may overburden existing radio channels.

B. Assessing the Departmental and Community Climate for Change

The strategies chosen for implementing the new plan should be based upon the attitudes of people in both the police department and the community. Particular attention should be given to anticipating whether an operations change, such as the implementation of a revised beat plan, will meet with a positive or negative reaction from patrol officers, supervisory personnel, and private citizens. In many cases, such a change will not encounter strong reactions from any source. However, extensive changes in patrol allocation or long-standing patrol policies may trigger strong opposition.

In assessing possible reactions to the new plan, it is helpful to remember that resistance may arise from individuals or groups who believe that a loss of prestige, power, share of agency resources, or favorable working conditions will result from the new plan. Reactions of patrol commanders, patrol officers, technical staff, the police union, community groups, and neighboring departments should be considered.

There are always some patrol officers and commanders who react adversely to any change. One investigator has found that the climate for change in a police department consists of the perceptions of department personnel along four dimensions:

- a recognition of the need for change,
- a perception that department personnel in general are open to change and possess a willingness to consider operational changes,

- a belief that the department has the potential or capacity for implementing operational improvements, and,

- a belief that department personnel are willing to participate in the design and implementation of operational improvements.[9]

It has been found that the first item above is negatively correlated to the other three; that is, the greater the perceived need for change, the less the perceived openness to change, potential for change, and participation in change efforts. If an unfavorable climate for change exists in the department--i.e., there is little recognition of the need for change, little perceived openness, potential, or participation in change efforts--more favorable attitudes toward change must be fostered by developing the foregoing perceptions among department personnel.

Community factors can also affect the implementation of patrol revisions. The attitudes of elected officials and citizens' groups need to be considered. Departmental relationships with neighboring jurisdictions may be affected, especially if there are agreements providing for mutual aid in emergency situations. Local or state legislation may indirectly impose constraints on patrol allocations--for example, by limiting the kinds of work schedules that may be used.

C. Smoothing the Way for Change

It is possible to promote a favorable climate for change. Information should be disseminated within the department which emphasizes the need for change and discusses both the shortcomings of existing policies and the anticipated benefits of the proposed change. Different points of view should be discussed openly. For example, objections may arise regarding an alleged disruption of service or other negative side effects of the change. Implementation plans and expected benefits should be specified in enough detail to counter such objections. Such an informational campaign should begin before the final beat plan has been produced.

Another way of developing a departmental environment conducive to change is by early involvement of key personnel from various staff levels in the planning process. As discussed in Chapter II, the participating individuals should be organized into a beat design task force responsible for the design, review, and implementation of new beat plans and other changes in patrol allocation.

D. Putting the New Plan Into Effect

By the time a new beat design has been agreed upon, a plan for actual implementation should already have been devised. This plan should contain both a description of the process by which the new beat design is to be implemented and a statement of the specific changes to be made.

Several tasks need to be included in the implementation process:

- selection of a date for implementation;
- a formal announcement of the change and implementation date; this may be limited to an in-house memorandum from the chief or patrol commander, or it may include a public announcement;
- final preparation of materials (e.g., new beat maps) and revision of dispatch equipment (e.g., status boards);
- briefing of appropriate command and supervisory staff regarding their responsibilities for various aspects of implementation; and
- training or briefing sessions for patrol officers and other line staff for the distribution of necessary materials and presentation of the required changes in operational policies and programs.

Since careful timing and coordination of these tasks is vital in producing an orderly transition to the new plan, a timetable for performing these tasks should be developed.

During the first several days of operations under the new beat plan, there should be careful monitoring for compliance with the new procedures and policies. Spot checks can be made of dispatching and reporting activities to ensure that the proper cars are being assigned to calls for service and that proper beat numbers are being recorded on incident reports.

E. Evaluating the Effects of the Change

Some departments may want to evaluate the new beat plans and patrol allocation changes to determine whether the objectives of the beat design effort were achieved. Just as clearly defined objectives are an important part of the beat design process, particularly when the hypercube system is being used, so are they also essential to any such evaluation. Therefore, planning for evaluation should begin early in the project, preferably when project objectives are first formulated.

It should be stressed that in most cases, the purpose of evaluation will not be to verify hypercube predictions about the new plan. Empirical data may differ from hypercube performance estimates for many reasons difficult to assess (see Chapter II). Nevertheless, project objectives may be achieved even though hypercube estimates are not reproduced in empirical data.

The evaluation of a new beat plan can be based on a relatively simple design, emphasizing one or two selected criteria, or the design can be very complex. The decision regarding the amount of evaluation effort should be based on several considerations, including:

- the degree of change from the previous plan,
- the importance attached to the changes implemented,
- the availability of empirical data from the previous plan, and
- the effort required to collect empirical data for the new plan.

Depending upon the objectives being evaluated, the assessment can include measures of patrol performance, officer satisfaction, and community reaction to the new plan. Measures of patrol performance can include the following:

- patrol workload by unit and by beat;
- cross-beat dispatching by unit, beat, and region;
- travel time by unit, beat, and region; and
- frequency of saturation (all units busy).

Table C-1 lists the specific data items that can be collected for each of these performance measures. Depending upon the desired level of sophistication, officer satisfaction and community reaction can be measured through the use of questionnaires, casual interviews, or routine monitoring of problems and complaints.

To assess the degree to which project objectives were achieved, empirical performance data for the old plan should be compared with similar data for the new plan. The primary consideration is the degree of improvement experienced as a result of the new plan. Usually, hypercube performance estimates for the old and new plans would not be used for this analysis.

Instead, performance comparisons ideally should be based on the actual number of patrol units deployed during time periods with equivalent workload patterns. In this way, it would be possible to avoid attributing to hypercube those performance improvements resulting from seasonal workload changes and informal deployment changes, such as deployment of fewer beat cars than intended or unofficial adjustment in beat boundaries.

Table C-1

PATROL PERFORMANCE MEASURES USED IN EVALUATING NEW BEAT PLANS

Performance Measure	Aggregate Statistics of Interest	Specific Data Items Needed for Each Time Period Examined
Patrol workload by beat	Total service time for incidents originating in each beat	Total number of incidents in each beat (CFS and patrol initiated) Number of cars dispatched to each incident Time each car was dispatched Time each car cleared the scene
Patrol workload by unit	Total service time for each patrol unit	(Same as above, plus the following:) Identity of cars dispatched to each incident
Interbeat dispatching by region	Percentage of incidents handled by cars other than the beat car	Total number of incidents for region (CFS and patrol initiated) Location of each incident (beat) Identity of cars dispatched to each incident
Interbeat dispatching by beat	Percentage of incidents in each beat handled by cars other than the beat car	Total number of incidents for each beat (CFS and patrol initiated) Identity of cars dispatched to each incident.
Interbeat dispatching by unit	Percentage of each car's dispatches that cause it to travel outside its beat	Total number of incidents handled by each beat car Location of incidents handled by each car
Travel time by region	For all calls in the region, the average amount of time between dispatch and arrival of a unit at the scene	Total number of CFS incidents in the region Time car was dispatched Time each car arrived at the scene
Travel time by beat	For all calls in each beat, the average amount of time between dispatch and arrival of a unit at the scene	Total number of CFS incidents in each beat Time each unit dispatched Time each car arrived at the scene
Travel time by unit	For all calls handled by each unit, the average amount of time between dispatch and arrival of a unit at the scene	Total number of CFS incidents handled by each car Time each car was dispatched Time each car arrived at the scene
Saturation probability	The percentage of calls that arrive when all units are busy	Total number of CFS incidents in the region Number of calls which arrived when no cars were available to respond

APPENDIX D

GLOSSARY OF COMPUTER MODELLING TERMS USED IN THIS REPORT

Computer Model: A mathematical model that is coded in a language which permits the model to be used and operated on a computer.

Descriptive Model: A model which evaluates the outcome if a specified policy is adopted, but which does not suggest alternative policies.

Interactive Model: A computer model designed and operated in such a way that the user can "communicate" directly with the model through a terminal by keying in instructions or data. Each instruction or collection of data is processed by the computer as soon as it is entered by the user. The computer's reply to the user's input, and model output are listed immediately on the terminal.

Model: A simplified representation of real-world processes used to investigate the relationships between variables, the effects of alternative policies or decisions, the outcomes of anticipated changes, etc. before the policies are implemented or the changes are made.

Non-Interactive Model: A computer model designed to be run without user/computer interaction. User instructions and data are prepared in advance on punched card, magnetic tape, etc. in the exact format and sequence required. Model output is listed on a printer or stored for later retrieval by the user.

Optimization Model: A prescriptive model which determines the "best" policy measured according to one or more specified criteria.

Prescriptive Model: A model which evaluates a specified policy and suggests alternative policies which will produce some improvement in one or more specified criteria.

REFERENCES

1. Bammi, Deepak, and Spencer B. Smith. "Design of Police Patrol Beats to Minimize Response Time to Calls for Service." Paper presented at the 43rd National Meeting of the Operations Research Society of America, May 11, 1973, Milwaukee, Wisconsin.

2. Bradshaw, Lt. Robert, and Jo Ann Moore. "Man-Machine Interaction for Police Field Manpower Allocation." San Jose, California: San Jose Police Department, n. d. (Mimeographed.)

3. California Commission on Peace Officer Standards and Training. "Patrol Workload Study: A Procedure for the Allocation and Distribution of Patrol Manpower." Sacramento: Commission on Peace Officer Standards and Training, December 30, 1974. (Mimeographed draft.)

4. Chaiken, Jan M. Hypercube Queuing Model: Executive Summary. R-1688/1-HUD. Santa Monica: The Rand Corporation, July 1975.

5. Chaiken, Jan M. Patrol Allocation Methodology for Police Departments. R-1852-HUD. Santa Monica: The Rand Corporation, September 1975.

6. Chaiken, Jan M., T. Crabill, L. Holliday, D. Jaquette, M. Lawless, and E. Quade. Criminal Justice Models: An Overview. R-1859-DOJ. Santa Monica: The Rand Corporation, October 1975. (Also available from the U. S. Government Printing Office, Washington, D. C.)

7. Chaiken, Jan M., Edward J. Ignall, and Warren E. Walker. A Training Course in Deployment of Emergency Services: Instructor's Manual. R-1784/1-HUD. Santa Monica: The Rand Corporation, September 1975.

8. Chelst, Kenneth. Implementing the Hypercube Queuing Model in the New Haven Department of Police Services: A Case Study in Technology Transfer. R-1566/6-HUD. Santa Monica: The Rand Corporation, July 1975.

9. Duncan, Robert B. "The Climate for Change in Three Police Departments: Some Implications for Action." Paper included in Innovation in Law Enforcement, U. S. Department of Justice, National Institute of Law Enforcement and Criminal Justice. Washington, D. C.: U. S. Government Printing Office, June 1973.

10. Eastman, George (ed.) Municipal Police Administration. Sixth Edition. Municipal Management Series. Washington, D. C.: International City Management Association, 1969.

11. Heller, Nelson B., William W. Stenzel, Allen D. Gill, and Richard A. Kolde, Field Evaluation of the Hypercube System for the Analysis of Police Patrol Operations: Executive Summary. Prepared under National Science Foundation grant APR75-17472. St. Louis: The Institute for Public Program Analysis, July 1977.

12. Heller, Nelson B., William W. Stenzel, Allen D. Gill, and Richard A. Kolde. Field Evaluation of the Hypercube System for the Analysis of Police Patrol Operations: Final Report. Prepared under National Science Foundation grant APR75-17472 St. Louis: The Institute for Public Program Analysis, July 1977.

13. Kolde, Richard A., Nelson B. Heller, William W. Stenzel, and Allen D. Gill. Instructional Materials for Learning to Use the Hypercube Programs for Analysis of Police Patrol Operations. Prepared under National Science Foundation grant APR75-17472. St. Louis: The Institute for Public Program Analysis, July 1977.

14. Larson, Richard C. "Approximating the Performance of Urban Emergency Service Systems." Operations Research, Vol 20, No. 5 (September-October 1975). (Also available from M.I.T. as IRP Report TR-12-75.)

15. Larson, Richard C. Computer Program for Calculating the Performance of Urban Emergency Service Systems: User's Manual. TR-14-75. Cambridge: Massachusetts Institute of Technology, March 1975. (Also available, slightly revised, as R-1688/2-HUD, from the Rand Corporation, Santa Monica.)

16. Larson, Richard C. "The Hypercube Model: An Introduction to Its Structure and Utility." TR-20-75. Cambridge: Massachusetts Institute of Technology, December 1975.

17. Larson, Richard C. "A Hypercube Queuing Model for Facility Location and Redistricting in Urban Emergency Services." Computers and Operations Research, Vol. 1, No. 1 (March 1974). pp. 67-95. (Also available as R-1238-HUD from the Rand Corporation, Santa Monica.)

18. Larson, Richard C. Hypercube Queuing Model: Program Description. R-1688/3-HUD. Santa Monica: The Rand Corporation, July 1975.

19. Larson, Richard C. "Illustrative Police Sector Redesign in District 4 in Boston." Urban Analysis, July 1, 1974.

20. Larson, Richard C. Urban Police Patrol Analysis. Cambridge: M.I.T. Press (Massachusetts Institute of Technology), 1972.

21. Larson, Richard C. Urban Public Safety Systems, Volume 1. Lexington (Massachusetts): Lexington Books, 1977.

22. Police Officer Deployment System: User's Manual. TEES 1056-76-2. College Station (Texas): Texas A&M University, December 1976.

23. Quincy (Massachusetts) Police Department. "Application of The Hypercube Model Sector Design Analysis." Quincy: Quincy Police Department, 1975

24. St. Louis Police Department. Allocation of Patrol Manpower Resources in the St. Louis Police Department. 2 Vols. Report prepared for the Office of Law Enforcement. St. Louis: St. Louis Police Department, July 1966

25. Smith, Spencer B. et al. "Superbeat: A System for the Effective Distribution of Police Patrol Units." Chicago: Illinois Institute of Technology, October 1973.

26. Sohn, R. L., and R. D. Kennedy. Patrol Force Allocation for Law Enforcement - An Introductory Planning Guide. JPL 5040-18. Pasadena: Jet Propulsion Laboratory, February 1976.

27. Weissberg, Richard W. Using the Interactive Hypercube Model. TR-17-75. Cambridge: Massachusetts Institute of Technology, June 1975.

28. Wilson, O. W. Police Administration. Second edition. New York: McGraw-Hill, 1963.

END