FIELD EVALUATION OF THE HYPERCUBE SYSTEM FOR THE ANALYSIS OF POLICE PATROL OPERATIONS: FINAL REPORT

THE INSTITUTE FOR PUBLIC PROGRAM ANALYSIS

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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 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 report summarizes the objectives of the project, describes the field test activities that took place, and discusses the results and products of these activities. Specific topics include: an overview of the hypercube system--a computerized planning tool used to evaluate alternative police beat structures and patrol deployment policies; case studies describing the field test experiences of 10 participating police departments; a discussion of the costs associated with using hypercube; assessments of the hypercube software and its performance estimates; a description of technology transfer efforts; recommendations for improvement, dissemination, and institutionalization of the hypercube system; and procedures for obtaining hypercube programs, documentation, training, and technical assistance.

PREFACE

This report summarizes the principal activities undertaken, and the major results obtained during 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). 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 participated in the project.

Other products of the study include the reports:

- How to Set Up Shop for Use of the Hypercube System - a report designed to help police planners and other potential users assess the benefits and costs of using the hypercube system;

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

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

These documents are available from The Institute for Public Program Analysis. A number of services have also been provided or initiated as part of this project. These services are documented in this report.

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, and of the various members of the law enforcement community who have served on the project's advisory board. These individuals and other key project participants are identified in Appendix B of this report. The contributions of the many other persons and organizations with whom the authors have corresponded, and who have assisted the project in a variety of ways, are also greatly appreciated.

A special note of thanks is also extended to Mr. Grant Buby, who assisted in the preparation of this report, and to Mrs. Vicki O'Dell, who typed most of the material appearing in the project's reports and supervised the typing of the remainder.

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CHAPTER I

INTRODUCTION

A. Historical Background and Overview of the Hypercube System

Development of the hypercube system began at the Massachusetts Institute of Technology in 1965 when Dr. Richard Larson formulated his hypercube queuing model for representing urban emergency service systems such as police patrol operations. This model was refined, computerized, and, to a limited extent, field tested as part of the Innovative Resource Planning project. That project was funded in 1973 by the National Science Foundation's program of Research Applied to National Needs, and was carried out by Larson and his associates at M. I. T. over a 24-month period. The computer programs which comprise the hypercube system were subsequently refined, documented, and field tested in New Haven, Connecticut, by the New York City-Rand Institute as part of a 1974 project, funded by the Department of Housing and Urban Development's Office of Policy Development and Research.

The results of these research efforts and the project documented in this report is a refined system of computer programs which use information based on police patrol operations and the geographic distribution of calls for police service to estimate police patrol performance statistics. The performance statistics that are estimated by the model include the following:

- average workload (i.e., the 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;*

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

- average travel times to calls for service throughout the region, in each beat, and in each 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 that is not within that unit's beat) for each unit, each beat, and the entire region;

- average frequency with which random points in the region and in each reporting area are passed by a unit on preventive patrol;

- fraction of calls throughout the region and in each reporting area to which a unit, other than the closest available, is dispatched; and

- fraction of calls for service that arrive when no unit is available to respond, and the resulting average travel time to these calls when the first available car is dispatched.

By comparing hypercube's field performance estimates for two or more alternative patrol policies or beat configurations, insights to many questions of interest to department planners and field commanders can be obtained. For example:

- Is one set of beat boundaries "better" than another set in terms of the major objectives of field patrol operations?

- How will field performance measures 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 be realized if automatic vehicle location equipment is installed?

- What effect will changing the distribution of preventive patrol coverage have on field perfomance measures?

- How will field performance be affected by alternative dispatching policies such as dispatching the "closest" available unit rather than an available beat unit, or the use of special (non-response) units to handle calls arriving when no units are available rather than queuing the calls until a response unit becomes available.

Conceptual use of the hypercube system is depicted in Figure 1-1, which illustrates the model's role as a planning tool, and the integral role of the planner as the decision-maker in the design process.

Several versions of the hypercube software now exist which permit the system to be implemented and accessed in a variety of ways. For example, one version is designed for interactive use on a time-share system. With this version, a police planner can describe the patrol policy and beat configuration to be analyzed in a "conversational" manner by responding, via a teletypewriter data terminal, to a series of questions posed by a computer program. The program analyzes the planner's response to each question to ensure that it is consistent with previously supplied information, performs other error-checking functions, and reformats the information for processing by another component of the hypercube system. Other versions of the hypercube system, designed for non-interactive use, are more suitable for implementation on data processing systems maintained by police departments.

B. Objectives and Activities of the Field Test Project

By the spring of 1975, use of the hypercube system had been explored by police departments in New York City and New Haven, Connecticut, and it had been implemented for the redeployment of patrol resources in the Massachusetts cities of Boston, Quincy, and Arlington. Hypercube implementation in these departments revealed a number of unresolved questions. Among these were:

- How accurate are the field performance estimates computed by the hypercube programs?
- What costs will be incurred by a police department using the hypercube programs to review and redesign its patrol beats?

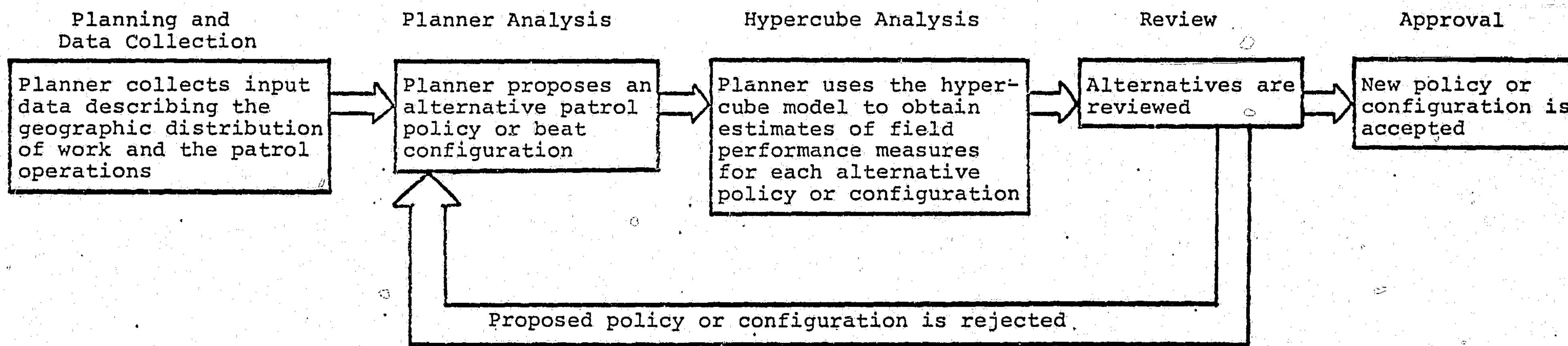

Figure 1-1

ITERATIVE DESIGN PROCESS USING THE HYPERCUBE SYSTEM

- How much technical assistance will police users of the hypercube system require in collecting input data, procuring data processing services and equipment, operating the computer programs, and interpreting hypercube output?
- How can the future dissemination and utilization of the hypercube system be accomplished, and the future availability of the programs, documentation, training, and technical assistance be assured?

Resolution of these four questions was the primary objective of the field test project begun in 1975 by The Institute for Public Program Analysis with funding through NSF's program of Research Applied to National Needs. The primary activities of the project are summarized in this section. More detailed discussions of each activity are presented throughout the remainder of this report.

The field test project was carried out in two phases: a six-month planning phase, and an eighteen-month field test phase. During the planning phase of the project, police departments in 10 cities belonging to the California Innovation Group, an NSF-funded consortium of cities involved in technology transfer, were surveyed to identify those departments interested in participating in the field test program, and to gather detailed information about each department. The results of the survey were used to design the field test phase, and identify the departments that would participate.

Sources of data processing services suitable for use during the field test were also surveyed during the planning study. After extensive benchmark testing of the hypercube system on three commercial time-share systems, National CSS, Inc.* was selected for use during the remainder of the project.

The planning phase also enabled members of the TIPPA research

*CSS is always abbreviated in the corporate title. It stands for Conversational Software System.

team to familiarize themselves with the hypercube software and documentation, identify needed changes and additions, and formulate plans for evaluating the software and assessing the accuracy of the model.

The field test phase of the project was structured around the following activities:

- Meetings and workshops - Representatives of the TIPPA research team, the participating departments, and consultants to the project participated in an orientation meeting, a training workshop, and a policy analysis workshop. The orientation meeting was held to discuss project activities and affirm each department's commitment to continued participation. The training workshop was held to familiarize department representatives with the use of the hypercube system. The policy analysis workshop, held near the end of the project, was used to discuss use of the hypercube system for patrol policy analysis, and to review the experiences of each department in analyzing, designing, and implementing new beat configurations. In addition, the TIPPA research team and the project advisory board met twice to discuss and plan project activities.

- Data collection and analysis - Prior to the training workshop, members of the TIPPA research team assisted the staffs of the police departments in collecting, tabulating, and analyzing department data to produce the input information required for the hypercube programs, and to provide the basis for subsequent assessment of the hypercube estimates.

- Data processing - Following the training workshop, representatives of the participating departments used the hypercube system to analyze and redesign their patrol plans with data terminals, data processing services, and over-the-phone technical assistance provided by TIPPA. Several of the patrol plans designed in this way were subsequently implemented.

- Assessment of the hypercube system - The hypercube software was evaluated in terms of both its usability by police department personnel without prior experience in using computers, and the accuracy of the hypercube performance estimates. Based on suggestions by department representatives, a number of changes were incorporated into the system to improve its usability.

- Information dissemination - Many project activities were directed at informing potential users in the law enforcement community of hypercube's availability and the potential benefits that can result from its use. These activities included direct contact with interested organizations, publication of articles and announcements in numerous journals, and hypercube presentations at several meetings and conferences.

- Institutionalization of the hypercube system - To ensure the future availability of the hypercube software and documentation, training in the use of the system, and technical assistance when required, several alternative methods for institutionalizing the hypercube system were investigated, and a recommended course of action was formulated.

C. Project Results and Products

The field test project produced the following answers to the questions identified above:

- How accurate are the field performance estimates computed by the hypercube programs? Assessment of hypercube's performance estimates indicate that they are sufficiently accurate to permit a planner to compare alternative patrol plans and select the one which best meets his department's objectives. Because the hypercube system estimates some performance characteristics previously unavailable, hypercube provides a valuable tool for planning patrol operations. In general, hypercube estimates do not duplicate empirical data in an absolute sense because of simplifying assumptions incorporated in the model, and inaccuracies in the raw data input to the programs.

- How much will a police department's use of the hypercube system cost? The major costs to a department using the hypercube system are personnel, data processing, and training and technical assistance. A complete beat design effort from initial planning to final implementation requires a minimum of two man-months of effort. The effort required for a department using hypercube for the first time may run as high as four man-months of full-time work. Data processing costs incurred by individual departments ranged from approximately $600 to $5,000 during the field test when an interactive version of the software implemented on a commercial time-share system was used. Technical assistance costs depend on the experience of department personnel with computer models. Departments in the field test project received an average of 10 man-days of training and technical assistance.

- How much technical assistance will users require? Users who have familiarized themselves with the hypercube system through self-study, or by attending hypercube training workshops, will require only a limited amount of technical assistance in collecting input data and operating the computer programs. Documents produced during this project will reduce the amount of technical assistance required by future users in these areas, and in the areas of procuring data processing services and interpreting hypercube output. Technical assistance needs will also be reduced if recommended repackaging of the software is achieved.

- How can the future dissemination and utilization of the hypercube system be accomplished? Dissemination of information to the law enforcement community about the availability and capabilities of the hypercube system began during the field test project through direct contact with interested organizations, publication of journal articles and announcements, and presentations at meetings and conferences. Recommended methods for continuing these dissemination efforts in the future were proposed. A recommended course of action was developed to assure that hypercube training and technical assistance, as well as copies of the software, will be available in the future.

In the process of answering these questions, the hypercube field test project has produced several useful reports. These included the following:

- How to Set Up Shop for Use of the Hypercube System - a report intended to help police planners and other potential hypercube users assess the benefits and costs of using the hypercube system;

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

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

These documents are available from The Institute for Public Program Analysis.

Services provided or initiated as part of the field test project included:

- Through training and other forms of technical assistance, the TIPPA research team assisted planners from eight police departments collect data, analyze existing patrol policies and redesign beat configurations, and, in some cases, implement and evaluate beat plans.

- TIPPA initiated several dissemination efforts to inform potential users of the availability and benefits of the hypercube system. These efforts included arranging for the appearance of articles and announcements about the hypercube programs in five national publications, and for notification of the software's availability to state planning agencies in public safety throughout the country. In addition, TIPPA designed and maintained an exhibit on the hypercube system at an NSF symposium, mailed hypercube information to hundreds of state and local agencies, presented papers on the hypercube field test at several meetings of professional societies, and introduced hypercube to police planners attending university short courses.

- Usability of the hypercube software was improved as a result of changes and additions to the hypercube programs identified during the field tests.

- An interactive version of the hypercube system was implemented on National CSS, Inc., an internationally-accessible time-share data processing system. Use of this version of the software is fully documented in the training handbook developed during the project. As a result, this hypercube system can be used by police departments without existing in-house data processing capabilities, and by planners without prior data processing experience or knowledge of the NCSS time-share system.

D. Structure of the Report

Chapter II contains a brief review of the experiences of the police departments which participated in the field test project. For each department, the data collection procedures utilized, the types of hypercube analyses performed, and the kinds of problems encountered, are discussed. The results of each department's involvement in the field test project, and the factors contributing to these results, are summarized. Chapter II concludes with a brief discussion of key elements in the successful use of the hypercube system based on the field test project and a survey of other hypercube users.

Chapter III discusses data collection, data processing, personnel, and technical assistance costs associated with use of the hypercube system. In addition to summarizing the costs experienced during the field test by the individual departments, procedures for estimating the cost of using the hypercube system are presented.

Chapter IV discusses the hypercube software and assesses the accuracy of the hypercube performance estimates. Changes made to the software during the field test project are summarized, and recommendations are presented for additional changes in current versions of the software.

Chapter V reviews the technology transfer efforts accomplished during the project, identifies the need for additional technology transfer activities, and presents several alternatives for meeting these needs. Topics discussed include information and software dissemination, technical assistance, and training.

Chapter VI draws upon the field test results to make recommendations for improvements in, and dissemination and institutionalization of the hypercube system. A plan for implementing the technology transfer activities identified in Chapter V is presented. This plan, if implemented, would significantly increase the number of police agencies that would have access to the hypercube system.

Appendix A contains detailed descriptions of the field test activities in Burbank, Fresno, and St. Louis County. The implementation of revised beat plans and patrol policies in these departments are also discussed. Key project participants are listed in Appendix

B; and the current sources of hypercube software, documentation, training, and technical assistance are identified in Appendix C.

CHAPTER II

FIELD IMPLEMENTATION OF THE HYPERCUBE PROGRAMS

A. Introduction

The field testing of the hypercube programs was conducted by The Institute for Public Program Analysis in cooperation with 10 police departments, nine in cities belonging to the California Innovation Group (CIG) and one in Missouri. CIG is an NSF-funded consortium of cities 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 city with day-to-day management and coordination provided by the CIG executive staff. The CIG cities are shown in Figure 2-1.

The 10 police departments participating in the project are listed in Table 2-1, along with information summarizing their respective jurisdictions. This many agencies were included in order to study the performance of the hypercube system under a wide range of conditions. (The departments serve cities with populations from 85,000 to 766,000, and utilize patrol plans requiring from 5 to 96 beats at any one time.)

The hypercube programs have attracted considerable attention among law enforcement agencies, and they have been utilized to some extent by police departments in New Haven (Connecticut), New York City, Boston, Quincy (Massachusetts), and Arlington (Massachusetts).

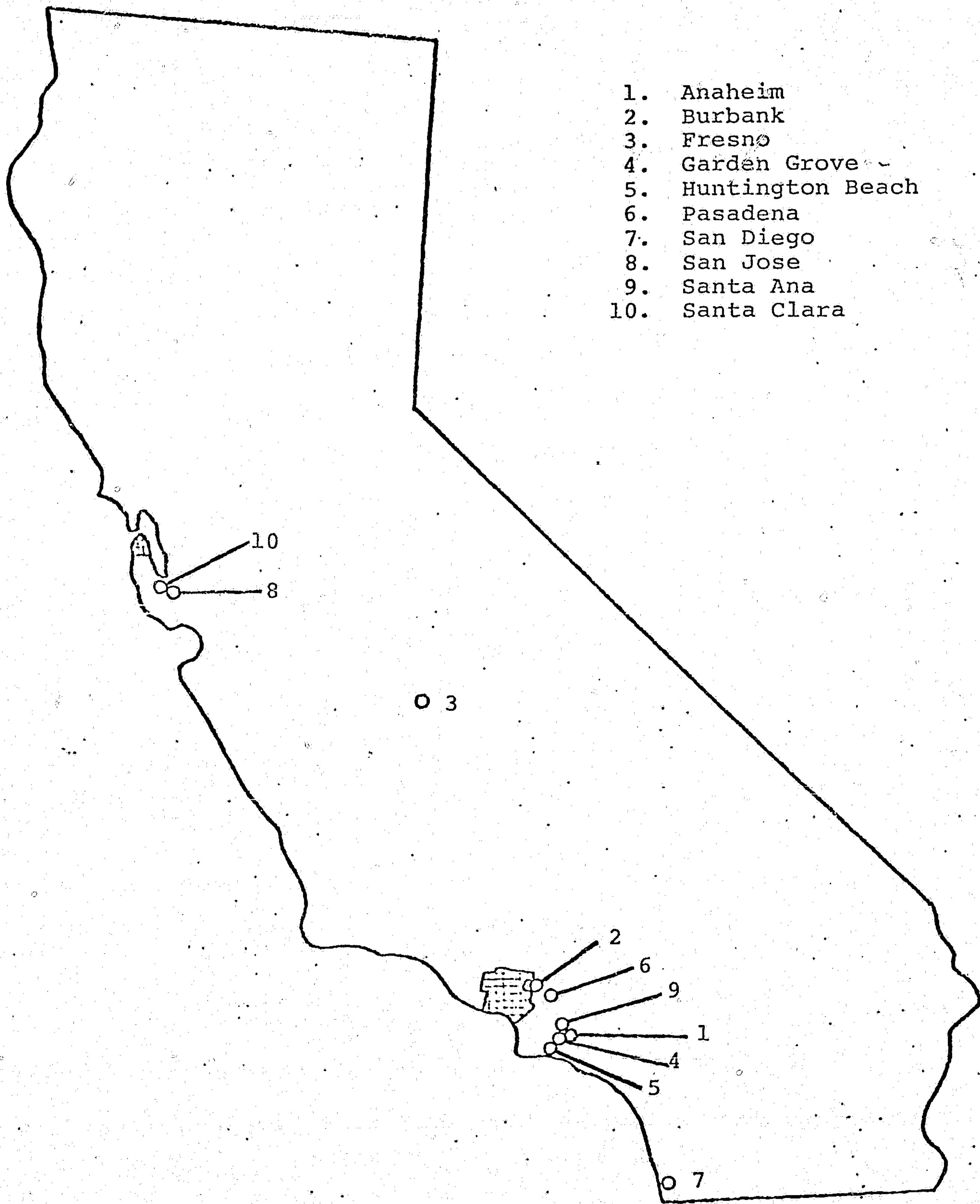

Figure 2-1

LOCATIONS OF CALIFORNIA INNOVATION GROUP CITIES

Table 2-1

BASIC INFORMATION ON FIELD TEST POLICE AGENCIES

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 CIG 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.

In addition, they have been the subject of training sessions for police planners at M. I. T. and at Northwestern University's Traffic Institute. The field test program was aimed at resolving some of the questions left unanswered by these previous users of the hypercube programs. Among these are:

- How accurate are the field operations performance characteristics estimated by the computer programs? (Can they be relied upon in planning patrol deployments?)
- What costs will be incurred by a police department which employs the hypercube programs to review and redesign its patrol beats?
- How much technical assistance will police users of the hypercube programs require, taking into account aid required in connection with the collection of input data, the procurement of data processing services and equipment, the operation of the programs themselves, and the interpretation of output?
- How can the future availability of the programs be assured, so that law enforcement agencies will be able to obtain copies of the programs and documentation, training in the use of the system, and technical assistance?

The implementation of the hypercube system in the participating police departments was designed specifically to answer the first three questions and contribute to the development of alternatives for assuring the future availability of the system. Also, the experiences of the 10 departments helped demonstrate how the hypercube programs may or may not be of value to departments in making key resource allocation decisions. Another product of the effort has been a set of field-tested training materials suitable for use by police planners learning to use the system.

The following sections describe the activities that comprised the field implementation portion of the project and summarize the experiences of the 10 departments involved in the project. More detailed case studies on three of the departments -- Burbank, Fresno, and St. Louis County -- are contained in Appendix A. Information on the evaluation of the hypercube software and validation of hypercube output is contained in other chapters of this report.

B. Overview of Field Implementation Activities

The field implementation and testing of the hypercube programs were structured around the following activities:

- planning survey,
- orientation and data collection,
- training-design workshop,
- police department use of the hypercube software with technical assistance from TIPPA, and
- policy analysis workshop.

It was hoped that all 10 participating departments would be involved in all field test activities, but two departments withdrew during the course of the project and others missed the final workshop due to schedule conflicts.

Planning Survey

During the planning phase of the field test project, TIPPA staff conducted a field survey of the police departments in the 10 CIG cities and St. Louis County. The field survey had two principal objectives. The first was to explain and demonstrate the interactive version of the hypercube system to police planners in each city to determine which departments were interested in participating in the field test program. The second objective was to gather detailed information about each department to serve as a basis for designing the field test and selecting the specific cities to be included. The information collected from each department included descriptions of both past and current beat design methods, identification of deployment and dispatching policies, the availability of data required for the hypercube model, and the planning capability of each department. Based upon the survey findings and other preliminary activities, detailed plans were developed for subsequent phases of the field test project.

Orientation and Data Collection

On May 14, 1976 an "orientation meeting" of field test participants was held in Pasadena, California. In attendance were chiefs of police, department planners, CIG science advisors and others from nine CIG cities, the director of planning for the St. Louis County Police Department, members of the TIPPA research team, executives of CIG, consultants, and Dr. Richard Larson, original developer of the hypercube model. The purpose of the meeting was to explain the project's objectives to all participants, to provide a detailed introduction to the hypercube methods and the data required, and to reaffirm the commitment of the participating police departments.

Following the orientation meeting and prior to the Training-Design Workshop, TIPPA staff revisited each participating police department to assist them in developing a plan for collecting data needed as input to hypercube, and to assess the availability of other data needed to validate the hypercube output. Following these visits, technical assistance was provided by telephone from TIPPA's office. The tabulation and analysis of raw data were provided by TIPPA if the departments were unable to carry out this task for themselves. Technical assistance from TIPPA during the data collection effort appeared to be an important factor in the successful completion of this work in most departments.

Training-Design Workshop

Planners from nine police departments attended a one-week "Training-Design Workshop" presented by TIPPA in Pasadena, on June 21-25, 1976 (one department had declined to participate further). Prior to the workshop, a handbook was developed for the participants' use, derived in part from existing documentation on the hypercube programs and in part from other police resource allocation and evaluation literature. Participants completed a series of simplified beat design exercises illustrating use of the hypercube programs, and then proceeded to examine their own departments' beat plans using input data previously compiled for this purpose.

Police Department Use of Hypercube

Following the Training-Design Workshop, participants took the portable data terminals to their own departments to begin the next phase of the project. This involved use of the terminals and the NCSS time-share system to complete analysis of their current field operations and to study possible beat plan revisions. TIPPA provided over-the-phone technical assistance to the planners as needed.

Two of the original departments did not participate in this phase of the project. One department withdrew due to the amount of effort that would have been required to collect the input data needed to use the hypercube programs. The other decided to drop out of the project following the training workshop since the department's patrol beats had recently been realigned, and the people who would have been using hypercube were occupied with implementing a new team policing program.

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

The remaining five departments made varying degrees of progress in their hypercube analyses. Table 2-2 shows the extent of hypercube usage by the 10 departments involved in the project; brief summaries of the departments' experiences are contained in the following section of this chapter. The appendix to this report contains more detailed case summaries on the use of the hypercube software by the three departments which implemented hypercube-designed beat configurations.

Policy Analysis Workshop

The Policy Analysis Workshop, held in December 1976, was the final activity involving the participating departments. The agenda for this two-day workshop included the following: distribution and discussion of revised and expanded training materials, sharing of feedback from participating departments regarding use of hypercube, and a brief presentation on use of the software for patrol policy analysis.

Table 2-2

EXTENT OF HYPERCUBE USE BY THE TEN PARTICIPATING POLICE DEPARTMENTS

Department	Areas/Times Selected for Analysis	Examination of Current Beats Completed?	Alternative Structures Examined?	New Beat Structure Proposed?	New Beat Structure Implemented?
Burbank	city-wide all times	yes	yes	yes	yes
Fresno	city-wide 5 time periods	yes	yes	yes	yes
Garden Grove	city-wide 5 time periods	partial	no	no	no
Huntington Beach	city-wide 3 time periods	partial	no	no	no
Pasadena	city-wide 3 time periods	partial	yes	no	no
St. Louis County	5 precincts 3 watches	yes	yes	yes	partial (2 precincts)
San Diego	1) city-wide (ambulance districts)	yes	no	no	no
	2) downtown patrol beats	no	no	no	no
San Jose	2 districts 4 time periods	yes	yes	no	no
Santa Ana	city-wide 3 watches	yes	no	no	no
Santa Clara	city-wide	no	no	no	no

C. Police Departments' Experience With Hypercube

This section contains a summary of each participating department's experience in using the hypercube programs. The intent is not to provide a thorough accounting of what happened, but rather to highlight progress made and major problems encountered in each department. Problems common to several departments are not detailed in each department's summary; thus, the fact that a specific problem is mentioned in connection with only one or two departments does not necessarily mean that other departments did not share the same problem. Also, there may not be any mention of some problems specific to the model itself, such as the fact that the model requires certain input data not routinely collected by most departments. Problems inherent in the hypercube software, technical assistance needs of hypercube users, and costs of hypercube usage are discussed in detail in other chapters of this report.

Burbank

From the time the Burbank Police Department was approached about the field test project, there was interest in participating. A need existed to bring the beat plan more in line with current patrol strength, even though the amount and type of crime had not changed significantly. Storage of police data on the city's computer was being considered, and it was felt that the beat structure and data collection procedures should be examined before computerized record-keeping was initiated. Also, it was felt that department personnel could gain valuable expertise through the training involved in the project.

Data collection presented a major obstacle, and there was considerable doubt about whether the data could be gathered at a reasonable cost within the time available. The department had no computerized data and no established system of geographical reporting areas. Before using the hypercube programs, the department had to design a reporting area system for the city and construct a data base by sampling dispatch tickets and officers' daily activity logs. The amount of effort involved seemed initially to be more than could be justified in terms of potential benefits to the department.

Members of the research team met with department personnel who would be involved in the project to discuss data collection efforts. Based on the plan developed, administrative aides in the department devised a reporting area system and collected sample data from dispatch tickets, assigning incident addresses to appropriate reporting areas. The research team had the data keypunched and processed for input to the hypercube programs.

Prior to the hypercube study, the Burbank Police Department had used the same 14-beat configuration for over 15 years. It was decided that for ease of administration the department would continue to use a single beat plan for all watches and days of the week. It was known, however, that current patrol strength was usually insufficient to allow one car per beat under the 14-beat plan. An average of 10 patrol units were being fielded during the day and swing shifts (8:00 a.m. to 4:00 p.m. and 4:00 p.m. to midnight) and even fewer units were being fielded on the night shift (midnight to 8:00 a.m.). Therefore, it was decided that the new beat plan should contain 10 beats divided equally between the two command sectors.

Based upon hypercube analysis of the 14-beat plan and approximate workload balancing, two alternative plans were developed for each sector. These initial plans also attempted to encompass distinct neighborhoods within the beat boundaries. Each plan was analyzed using the hypercube programs, with particular attention given to workload balancing and minimizing cross-beat dispatching. Based upon analysis of hypercube output, a new beat plan for each sector was presented to field commanders and approved for implementation.

Several factors helped make the Burbank experience a positive one:

- Technical assistance from TIPPA, especially during the data collection effort, enabled the department to successfully complete what at first seemed to be an impossible task.
- There was a recognized need to reexamine the old 14-beat configuration.
- The department was willing to try a different method of data collection in order to complete the study.

In spite of the good results obtained by the department, continued use of hypercube in Burbank is not anticipated. The use of a static beat plan and the stability of the city's population and crime patterns mean that major beat revisions will probably not be necessary in the near future. The reporting area system devised for the hypercube study will probably not be used for on-going data collection by the department, and the planner trained in hypercube operation has left the department. Therefore, the amount of effort involved in implementing another hypercube study would be difficult to justify in view of the limited additional benefits of such a study to the department. (More detailed information on the Burbank Police Department's use of hypercube is contained in Appendix A.)

Fresno

Prior to the hypercube study, the Fresno Police Department had used the same 16-beat configuration for over 10 years. This plan was used on all shifts and all days of the week. Approximately the same number of officers were deployed on each of the three working shifts (7:00 a.m. to 3:00 p.m., 3:00 p.m. to 11:00 p.m., and 11:00 p.m. to 7:00 a.m.), and additional manpower was deployed on a "lap" shift (7:00 p.m. to 3:00 a.m.). The units assigned to the lap shift provided back-up assistance for the regular beat cars.

The limitations of this manpower allocation plan had long been recognized, but previous analyses could not successfully justify proposed changes due to a lack of data. In recent years, however, the police department and the city's data processing center have worked together to improve the department's data collection capabilities. The city has been divided into 249 "zones" with areas of approximately 0.25 square miles, and workload data have been captured by hour and zone. Workload information gathered includes citations, offenses, arrests, court appearances, offense clearances, dispositions, and accidents. The availability of these data has greatly enhanced the department's ability to analyze patrol operations, and most of the basic hypercube input data were available through the data processing center.

Hypercube was especially appealing because of its ability to show the inter-relationships between workloads, response times, preventive patrol levels, and cross-beat dispatching. The data processing center could provide these data, but could not combine them into an integrated analysis of alternative beat designs. Also, the department was preparing to implement a computer-aided dispatching system (CAD), and wanted a beat design study completed before final CAD implementation. Thus, the use of hypercube coincided with existing department priorities.

The old 16-beat configuration and possible alternatives were examined for five different time periods. It was found that there were sufficient personnel assigned to the patrol division to handle the generated workload, but serious utilization imbalances were found among the various beats and times of the day. As a result, patrol manpower was redistributed among the four overlapping shifts, and a separate beat plan was developed for five different time intervals examined. Under the new plan, the number of beats varies from 13 (3:00 - 7:00 a.m.) to 29 (7:00 - 11:00 p.m.).

The actual implementation of the new plan proceeded quite smoothly, and the department is considering using hypercube to periodically assess beat performance. A report has been issued by the department to describe the use of hypercube and the results of its efforts.*

Several factors contributed to the success of the beat design effort in Fresno:

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*"Beat Design and Manpower Deployment System," Fresno Police Department Administrative Services Bureau (James L. Packard, Deputy Chief), November 1, 1976.

- There was a recognized need for revision in patrol allocation and beat structure.
- Many of the data items needed were readily available.
- The formation of a department task force to supervise the project helped assure the 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.

The success of the Fresno effort is particularly noteworthy because of the rather drastic changes made, i.e., from a static beat plan to plans which vary nearly every four hours. Many departments find such variation in beat plans to be administratively unacceptable, but such a reallocation of patrol resources was seen as necessary to reduce the excessively high patrol unit workloads previously common to some times of the day.

(More detailed information on the Fresno Police Department's use of hypercube is contained in Appendix A.)

Garden Grove

The planning effort in the Garden Grove Police Department was hampered initially by a lack of readily available data, and later, by a reorganization of the patrol division. Plans had been made for examining the performance of the department's beat plans, which called for six to eight beats, during four different time periods, but very little of this work was actually accomplished.

The department uses a reporting area system, which divides the city into 91 areas. Serious crimes are tabulated by reporting area, but patrol activities are not. As a result, sample data from dispatch records had to be collected to provide reporting area workloads, incident rates, and service times. Ten percent of all calls for service and officer-initiated incidents from December 1975 through May 1976 were analyzed. Response speed data was gathered by field observation.

The patrol division was reorganized and new beats were implemented in July 1976 following the appointment of a new police chief. The reorganization was based on plans made before the hypercube study began. In addition, planning was begun for the adoption of a team policing plan in 1977, with patrol teams assigned to school district areas. Toward the end of the project, some hypercube runs were made on possible team policing deployments, and the results may later be used in the final planning for the team policing program.

The Garden Grove experience illustrates how other priorities can affect a hypercube study, especially when there is only a marginal commitment to the study in the beginning. Although these shifts in priorities cannot always be foreseen, it is advisable that an effort be made to assess their potential impact prior to initiation of hypercube analysis.

Huntington Beach

The hypercube study in the Huntington Beach Police Department was initiated as a low priority project, and when problems arose with the collection of hypercube input data, and other department projects demanded increased attention, the hypercube study was halted. The planner working on the study did manage to collect all of the necessary data and make several successful runs, examining the existing beat structure and one possible alternative plan. However, the data produced have not been used in making any decisions about field patrol operations.

The department has used a variety of sophisticated management tools, and there was interest in exploring the potential uses of hypercube. The department has implemented a CAD system, has detailed computerized data available on patrol operations, and is currently implementing an automatic vehicle locator (AVL) system. But despite the interest in hypercube, the commitment to a hypercube study at the time was marginal for several reasons:

- There was no pressing need for revising the current beat structure.
- The department could not commit itself to making beat revisions which would require revising CAD programs.
- Major emphasis was being placed upon AVL implementation and development of management reports associated with it.
- Future AVL use would diminish the need for well-defined beat boundaries.

It was hoped that computerized management reports would provide most of the hypercube input data with little data collection effort. However, it was found that much of the data produced was not compatible with hypercube requirements. Rather than embark upon a time-consuming data collection effort, existing data were used with some modifications. For instance, citations and incidents resulting in the writing of a department report are tabulated by reporting area, but total patrol workload is not. The distribution of the former was used as the distribution of total patrol workload, on the assumption that the two distributions would be equivalent.

The shortcomings of the input data added to the doubts about hypercube's usefulness to the department. The planner working on the hypercube study was also developing management reports to use CAD and AVL information, and the hypercube study was eventually set aside in favor of these other projects.

The Huntington Beach experience shows the danger of embarking upon a hypercube study as a low priority project, presuming that little data collection effort will be required. An early assessment of hypercube data requirements and available department data can yield a fairly clear picture of the amount of effort required to produce the desired level of reliability.

Pasadena

The hypercube beat design study in the Pasadena Police Department accomplished only a portion of what was originally planned. Plans had been made to examine the performance of the existing seven-beat plan and possible alternative plans during three separate time periods. Only two time periods were examined, and no alternative beat configurations were proposed for implementation. Reasons for the slow progress of the study included the following:

- The current beat plan was implemented in 1975, and neither field nor command personnel had identified a pressing need for change.
- Planning resources in the department are limited; the small Administrative Services Bureau has handled the hypercube study, but it has other duties such as budgeting and the management of federal programs.
- Field and command personnel have a general mistrust of computers based on past experiences, and even the planner using the system had misgivings about the input data used and the ways in which the system models the department's operation.

The department has no computerized data, so workload data for hypercube had to be collected from a sample of dispatch tickets. The original sample used consisted of all dispatch tickets from

May 12, 1976, through May 27, 1976. This sample was later expanded to include July calls, so that the final sample consisted of 35 days (five of each day of the week). Data were coded by clerks in the department and sent to TIPPA for processing prior to the Training-Design Workshop. Approximately 6,300 incidents were included in the sample, but some types of incidents were excluded as not being part of patrol force workload; among those incidents excluded were those handled by station personnel and those handled by designated "report cars," which respond only to routine report-taking calls.

Difficulties were encountered in modeling some department operations and estimating some input data items. These difficulties stem from operational practices which cannot be modeled by the system, and the fact that the system calls for data not routinely collected by most departments. For example, the Pasadena Police Department uses priority dispatching and call stacking at the beat level, rather than having the dispatcher hold calls. These practices make it difficult to estimate service and travel times. Also, there were no data available on the time spent by patrol units for various administrative duties (vehicle maintenance, warrants, transporting prisoners, briefings, etc.). Subjective estimates were used for these data items, diminishing the confidence that could be placed upon hypercube performance estimates.

Field personnel were not involved in the hypercube study, but the study was discussed at uniform division meetings. No task force was formed to consider the implications of hypercube output or propose alternative beat plans; any beat plan changes which might have been recommended by the planner would have been presented to watch commanders for consideration. Selling a new beat plan to field personnel would have been difficult because of their mistrust of computers and the lack of serious problems with the present plan. The main beat design criterion used in the past has been unit workload which dispatchers have tended to informally balance. Hypercube output allows examination of a broad range of performance measures, and there is some doubt that field personnel are prepared to consider data of such amounts and complexity.

Future use of hypercube in Pasadena is doubtful. The study seemed very much dependent upon the 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 seem likely in view of its limited usefulness to the department.

The experience of the Pasadena Police Department is valuable in that it illustrates several points which may affect the use of the system in other departments:

- 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.
- Much of the required hypercube input data is not routinely collected in many departments, so that extra time must be spent on collecting data and/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 a planner with some data analysis expertise.
- Departments with a small planning and analysis staff may be unable to allocate an uninterrupted span of time to work with the hypercube. Other high priority tasks

may interrupt hypercube operations for a sufficiently long time that the planner must take time to reacquaint himself with hypercube.

- The hypercube analysis may indicate that only a very minor improvement could be made in the beat plan. The value of a minor improvement has to be compared to the cost involved in training personnel and changing procedures to accommodate a different beat plan. The intangible cost of resistance to change must also be evaluated.
- Some departments may not have any funds budgeted for unanticipated data collection or data processing. Furthermore, such special projects must generally be planned months before the actual expenditures occur since funds can be requested or obtained only at certain times of the year. The only practical alternative is to reduce available funds for other projects and spend the money on hypercube. This is difficult to achieve in a department which is already operating within a very restricted budget.

St. Louis County

Designing patrol beats for the St. Louis County Police Department is a difficult task. Each of the department's five precincts operates as a separate command area, so each requires separate beat plans. In addition, all of the precincts vary beat boundaries by watch. Consequently, a total redesign of patrol beats requires 15 separate plans. Significant workload differences also exist within the approximately 350 square miles served by the department since the jurisdiction contains densely populated urban areas and sparsely populated rural areas.

When given the opportunity to participate in the field test project, the response within the St. Louis County Police Department's Planning and Research Bureau was immediately affirmative. Much of the data needed for hypercube input was readily available in computerized form, and the bureau had already been given a directive from the police superintendent to produce a new beat design and manpower allocation plan by the end of 1975.

The only obstacle to the department's participation was the project's timetable. The actual work of designing new beats was not scheduled to begin until after the January 1, 1976, deadline facing the bureau. However, since the department could easily produce most of the necessary input data and was located near the Institute's offices, arrangements were made for a police planner to use TIPPA's data terminal during November and December (1975) for the purpose of analyzing proposed beat plans using the hypercube programs.

The Superintendent wanted the redesign to be conducted by the planning and research bureau without the input of precinct commanders. Unit workloads were to be equalized in each precinct on each watch, so the entire effort consisted of three steps: allocation of department manpower to precincts according to precinct workloads, allocation of each precinct's manpower to the three shifts according to shift workloads, and design of beat plans for each watch in each precinct. A total of 15 separate plans were produced using hypercube.

The five precinct commanders objected strenuously when the new plans were presented, and as a result, none was implemented. The main objection was that the commanders had not been involved in the formulation of the manpower allocation plan upon which the new beat designs were based. Also, workload equalization was questioned as a suitable manpower allocation and beat design objective, and questions were raised about the data used to measure workload.

The 1975 effort did show that the first precinct was undermanned, and in the spring of 1976, additional patrol manpower was allocated to that area. Consequently, new patrol beats were needed, and the planning and research bureau was again called upon to develop the plans. This redesign effort, however, was accomplished through a joint effort by a planner and the precinct commander; in fact, it was the commander who drew the tentative plans which were analyzed using the hypercube programs. New beats were agreed upon and were implemented in April 1976.

The 1975 study had also shown the fifth precinct to be undermanned, and the construction of a large shoppping center in a previously undeveloped area promised to further increase the precinct's workload. In the fall of 1976, additional manpower was allocated to the fifth precinct, necessitating the development of a new allocation of manpower by shift, and new beat plans for each shift. As in the case of the first precinct, this redesign effort was based on cooperation between the planning and research bureau and precinct personnel. Specifically, a planner worked closely with a lieutenant designated as liaison by the precinct commander, responsible for securing the necessary input from precinct officers. The use of the hypercube programs was fully explained, and hypercube output was shared with the lieutenant, who explained the findings to other precinct personnel.

There was considerable discussion concerning the number of beats to be manned during each shift. Two alternative allocations were proposed and alternative beat plans were drawn for each allocation. Hypercube output was used in the process of deciding upon the alternative which seemed to offer the most equitable balance in utilization and response times. Based upon these discussions, one of the proposed allocations and beat plans was chosen for implementation.

Several of the tentative guidelines suggested during the planning stage of the field test project have been validated in the experience of the St. Louis County Police Department. These are as follows:

- There is a need to have agreement on beat design objectives before redesign work is begun. (The hypercube programs assume that in the iterative design process the planner has a set of goals and preferences with which to trade off conflicting objectives.)
- There is a need to have agreement on a manpower allocation plan prior to initiating the beat design process.
- Field commanders having responsibility for implementing and supervising patrol operations need to be involved in the beat design process.

More detailed information on the St. Louis County Police Department's use of hypercube is contained in Appendix A.

San Diego

The San Diego Police Department entered the field test project in hopes of testing the application of hypercube to a limited area of the city. Based upon this test application, a decision could be made on hypercube's future usefulness to the department. There was no pressure to revise the current beat structure. The department has a sizable research and planning unit and considerable amounts of computerized management data, but even so, the hypercube study turned out to be more complicated than originally anticipated. As a result, most of the initial plans were not carried out.

Several difficulties hindered the progress of the hypercube study. First, San Diego is so large (310 square miles, 253 reporting areas, and up to 96 beats) that modeling the entire city in a single hypercube run would be prohibitively expensive. However, the city is difficult to partition into areas that can be modeled separately. The patrol force is divided into three divisions, each of which has "lieutenant's zones" and "sergeant's zones." Also, four radio frequencies are used. Patrol data are collected by census tracts, which are too few in number for detailed beat analysis (e.g., there are only two tracts per beat in many areas). Because the city contains large undeveloped areas with few roads and significant natural travel barriers, hypercube's method of computing travel times was considered to be less than reliable; however, alternatives were not considered feasible in terms of the data available and the effort required.

Data were collected for an area in the central part of the city, but no analysis was ever performed. Instead, several city-wide analyses were made for the city's ambulance service, which is operated by the police department. Fifteen ambulances are operated, and each has a designated response area. Hypercube was used to examine the performance characteristics of these ambulance districts.

In terms of patrol operations, it was decided that analysis of the allocation of patrol units by watch, by day of the week, and by command area was the most urgent need. This analysis would be very tedious to perform with hypercube, and would be more easily accomplished with Rand's Patrol Car Allocation Model (PCAM). Hypercube could then be used to "fine tune" the beat structures for each area and time. With this in mind, the department set aside the hypercube study and concentrated on implementing PCAM.

The outcome of the San Diego hypercube study confirms the value of advance planning in the use of hypercube. A review of model documentation and related material can yield a fairly accurate assessment of the amount of work that will be required and the suitability of the model for use by a particular department. Also demonstrated is the need for a commitment to hypercube use on the part of the field and command staff; this commitment should be based upon an informed assessment that hypercube can assist department planners in meeting recognized department needs.

San Jose

The San Jose Police Department's participation in the field test project was limited to the analysis of the beat plan for two of the department's seven districts. This was intended to be a pilot or experimental use of hypercube, with a decision to be made later on whether to attempt a full-scale hypercube analysis. The reasons for this limited participation were several:

- The department implemented new beat plans in 1974 after an extensive beat analysis using IBM's prototype Geodata Analysis and Display System (GADS).
- The department is in the process of implementing a computer-aided dispatching system and would be reluctant to change beat boundaries since this would require some CAD reprogramming.
- The beat maps used by the department are quite detailed, and would be expensive to revise if new beats were implemented.
- A grant application had been made for a project (Patrol Emphasis Program) to evaluate various patrol strategies.
- Although a reporting area system was devised for the 1974 beat redesign, incident data have not been routinely

collected by reporting area; to construct such a data base for the entire city would have been very time-consuming.

Despite these limitations, the department's planning and research division was interested in the hypercube system because of its unique capability to analyze interbeat dispatching and travel times as well as workloads. However, it was felt that the system would be more useful and attractive to police planners if it had some of the mapping and display capabilities of GADS. There is a possibility that the Patrol Emphasis Program may explore ways of linking the two systems.

The 1974 beat redesign effort included partitioning the city into 280 Beat Building Blocks (BBBs), but incident data is not routinely collected by BBB. However, sample data from 1974 were available by BBB, and these data were used in order to minimize the data collection effort required. This sample consisted of incident data from 28 days between May 1 and December 31, 1974. It was initially decided that only the Second District would be examined, so that the areas and center coordinates would have to be computed for only 35 BBBs. However, the First District, with 60 BBBs, was also examined during the project.

Within each district, beat plans were examined for four time periods during which manning levels remain constant: 8:00 a.m. to 5:00 p.m., 5:30 to 10:00 p.m., 10:00 p.m. to 3:00 a.m., and 3:00 to 7:30 a.m. During the intervening time periods, manning levels increase due to shift overlap. Existing beat plans were analyzed, and some additional runs were made with various high-workload beats split in half. The only field operations change being considered as a result of this analysis is the possibility of adding an additional car to some beats.

The planning and research division arranged two hypercube demonstrations for field commanders. The purpose of these demonstrations was to make the commanders aware of hypercube and its potential uses. Copies of hypercube output were distributed to show the performance of a busy beat and the effect of adding an additional car. These sessions lasted between one and two hours, and involved a total of 20 field personnel.

The reactions of field personnel were mixed. Most had seen GADS being used and some had difficulty distinguishing between the capabilities of the two systems and the new computer-aided dispatching system. Some seemed to have a good appreciation of the output statistics. Others said they knew their areas and people better than any computer could. The inability of hypercube to model prioritized dispatching of calls was seen as a major shortcoming, since this is fairly common in San Jose.

The main possibility for continued use of hypercube in the San Jose Police Department is as an adjunct to the Patrol Emphasis Program. Due to the amount of time, money, and effort involved in creating a city-wide data base for hypercube, revising the CAD programs, and creating new beat maps, serious defects in present beat structures would have to be demonstrated before a major redesign effort would be authorized.

Due to the limited nature of the San Jose Police Department's use of hypercube, few general conclusions can be reached. The existence of other priorities was recognized from the outset, which enabled the department to make a realistic assessment of the amount of effort that could be devoted to the hypercube study.

Also, the misgivings of some patrol personnel about hypercube show the importance of involving patrol representatives in planning and supervising the design effort.

Santa Ana

At the time the Santa Ana Police Department was approached about participating in the field test project, the department was preparing to implement team policing. Previously, the department had been divided into eight patrol districts, with four or five beats in each district. The team policing plan did away with beats and allowed each team to design its own patrol plan.

Despite the implementation of team policing there was some interest in using hypercube to compare the performance of the new system with the old. A good computerized data base was available for the old beat system, so Santa Ana was selected to make trial hypercube runs during the planning phase of the field test project. Two days' efforts by a department planner, working with technical assistance from the TIPPA staff, produced usable performance data for the department, and allowed the TIPPA staff to observe the use of the hypercube programs with actual police department data. This experience was a valuable part of the study's planning phase.

The department did not, however, get to the point of analyzing the new team policing plan. A department representative attended the Training-Design Workshop, but did not have sufficient data to complete the team policing analysis. Shortly thereafter, the department withdrew from further participation in the project for the following reasons:

- Data required as input for a city-wide beat plan analysis were not readily available; the change to team policing had made some data difficult to obtain.
- Because of a perceived high volume of cross-district dispatching, it was felt that only a city-wide hypercube analysis would be appropriate, involving a minimum of 30 cars; runs of this size would result in high computer costs and would produce output tables which would be difficult to read and interpret.
- Since the team policing plan had been recently implemented, no changes in field operations would be considered for at least one year; consequently, use of hypercube to consider alternative deployments was seen as having little benefit for the department.

The withdrawal of the Santa Ana Police Department from the field test project was therefore based upon an assessment of other department priorities and problems in applying hypercube to the department's needs. This assessment was based in part upon the limited use of hypercube by a department planner during the planning phase, but it illustrates the importance of this kind of assessment to a department considering the use of hypercube.

Santa Clara

The Santa Clara Police Department was quite interested in participating in the field testing of the hypercube programs, but data collection problems forced the city's withdrawal from the project shortly after the orientation meeting.

In 1974, a city-wide reporting area system with 50 "zones" was developed, and there was some enthusiasm about using the zone system for the first time as a means of structuring patrol beats. A new amusement park was being built in a previously low-workload area, and the chief was interested in an overall analysis of patrol policies. However, gathering the necessary data on patrol activities proved to be more difficult than originally anticipated. Only serious crimes were tabulated by zone, and most patrol data were aggregated only by beat. To construct the input data base, it would have been necessary to collect data on calls for service from dispatch cards and data on self-initiated work from officers' daily log sheets. Even though only a small sample would have been required, it was felt that the department could not spare the manpower needed for such an effort.

An alternative plan was to have dispatchers immediately begin assigning a zone number to all calls received. Since the city has a civilian police-fire dispatching center, such a change would have required the city manager's approval. After much discussion, the police chief and patrol commander decided that the effort involved was more than the potential benefits to the department could justify. Instead, efforts were to be concentrated in improving some of the data collection weaknesses brought to light during the department's brief involvement in the field test project.

The assessment of the effort required for hypercube implementation was carried out with the assistance of TIPPA staff, but this same assessment can be accomplished through a thorough review of hypercube literature. This assessment can surface issues such as those which caused the Santa Clara Police Department to withdraw from the field test project.

D. Survey of Hypercube Owners

Concurrent with the field test phase of the project, an effort was made to identify and contact persons and organizations which had purchased the hypercube programs for their own use.

Twenty-four hypercube owners were identified. Of these, nine were police agencies, four were other municipal or criminal justice planning agencies, and 11 were other organizations, including research and consulting firms and university-affiliated organizations. Six had obtained the programs from the Rand Corporation and the other 18 had obtained them from M. I. T.; 12 had interactive versions of hypercube, and 12 had non-interactive versions.

A brief questionnaire was drawn up by TIPPA and sent to the 24 hypercube owners. Twelve responses were received. Of those responding, six stated that they had purchased the programs for implementation in local police agencies or criminal justice planning agencies; four were intending to use the program as part of research and consulting efforts; one intended to use the programs as a teaching tool and one did not respond to that question.

Only six respondents had actually implemented the programs, and only two had actually completed any analysis of police field operations. None of the respondents had received any training in hypercube use, although one mentioned being introduced to hypercube at an M. I. T. short course. Those who had not used the programs mentioned several reasons for not doing so: difficulty in selling services to police departments, data collection difficulties, lack of a PL/I compiler necessary to implement the software, and the existence of other priority projects.

Eight respondents mentioned the use of other police resource allocation software. Seven of these had PCAM, and one had both PCAM and programs for designing work schedules. One person commented that PCAM had been too complicated to use, and another commented that hypercube was the easiest resource allocation model to use.

When asked about future plans for hypercube usage, four respondents stated their intention to proceed with the implementation of the model in local police agencies, and four stated an intention to use hypercube in the course of research or consulting efforts. One intended to use hypercube as a teaching tool. One respondent was not sure how hypercube would be used, and two stated that the model would not be used by them in the future. Additional comments were made that financial constraints and resistance to changes in patrol allocation would hamper the use of hypercube.

When asked if they would recommend hypercube to others, five respondents said they would, although one of these persons warned that he would recommend the model only for those seriously interested in using it. The other seven respondents either did not respond to that question or stated that they could not judge at this time whether or not to recommend the model to others.

E. Summary of Field Test Observations

Several observations have been made in preceding sections regarding the use of the hypercube programs in the police departments participating in the field test project. As previously noted, these do not include observations about the hypercube software itself, the technical assistance requirements of hypercube users, or usage costs, as these are discussed elsewhere in this report. These observations are reiterated here to summarize the collective experiences of the 10 participating departments and other hypercube users.

1. <u>Lack of agreement on a manpower allocation plan can endanger the success of the beat design effort.</u>

The design of geographical patrol beats is based upon a manpower allocation scheme which determines the number of patrol units to be fielded by time of day, day of the week, and command area. Adverse reactions to new beat plans may be based upon the number of beats as well as their structure. The hypercube programs may be used to examine alternative allocations of patrol manpower, but such analyses can be tedious and expensive. If manpower allocation by watch, day, and command is an important issue, the use of PCAM may be appropriate prior to hypercube analysis.

2. <u>Agreement on beat design objectives is needed prior to the start of actual design work.</u>

The hypercube's iterative design method assumes the planner has a set of goals and priorities with which to trade off conflicting objectives. Hypercube allows consideration of a much broader range of objectives than other design methods, which may lead to the emergence of priorities previously ignored for lack of data. Without agreement on beat design objectives, the amount of hypercube output data can overwhelm the user and disagreements can arise during the design and implementation process.

3. <u>There must be a recognized need for redesign of patrol beats.</u>

The use of hypercube requires a considerable investment in terms of personnel time. In addition to the time a planner must spend learning to operate the system, collecting the input data, and analyzing alternative plans, time must be spent with command and patrol operations personnel to acquaint them with the system, review alternative configurations, and implement the new plan. The commitment of the time necessary is not likely unless it is agreed that the effort is important to the department.

4. Considerable effort may be required to collect input data and analyze output data.

Hypercube calls for input data not routinely collected in most departments, so a special effort will have to be made to collect or estimate some items; in departments with no computerized data, this effort can be considerable. Also, hypercube may not easily model some patrol operations common to many departments; therefore, adjustments may have to be made in input or output data to approximate these operations. As a result, the services of a planner or consultant with data analysis experience may be required. In departments with small planning and research staffs, it may be difficult to allocate an uninterrupted span of time to the hypercube study; other tasks may interrupt hypercube use so that the planner may have to occasionally reacquaint himself with the system. This further increases the amount of time required to complete the redesign process.

5. An assessment should be made prior to hypercube implementation to determine whether the amount of effort required is appropriate for the potential benefits of the study.

Before the decision is made to proceed with hypercube implementation, an assessment should be made to determine the amount of effort that will be required in terms of data collection, number of distinct plans to be produced, etc. The anticipated level of effort can then be weighed against the need for beat redesign and the existence of other department priorities. Hypercube analysis may indicate that only minor improvements can be made, in which case the effort involved in the study might not be justified; on the other hand, if extensive changes are indicated, additional effort may be required in the implementation process.

6. <u>Field operations personnel need to be involved in the beat design and review process.</u>

Field commanders are responsible for the implementation and supervision of patrol operations. There is likely to be some resentment if they are called upon to implement beat plans which they have had no part in designing. Their input can be valuable to the planner since they have the most intimate knowledge of travel barriers, access routes, and workload patterns. They may have beat design objectives and priorities different from the planner's. Also, their involvement may help overcome any misgivings about the use of a computer in designing patrol beats.

CHAPTER III

DATA PROCESSING AND OTHER COSTS OF USING THE HYPERCUBE SYSTEM

The purpose of this chapter is: (1) to identify the types of costs associated with using the hypercube system, (2) to quantify the magnitude of the various costs by summarizing the expenses incurred by each department participating in the hypercube field tests, and (3) to provide guidelines which will enable potential hypercube users in the future to estimate the costs they will incur in using the hypercube system to design police patrol beats for their own department. Costs are classified as follows:

- data processing costs - the costs associated with setting up, maintaining, and using the hypercube system;
- data collection costs - the costs associated with collecting raw data from department records (e.g., incident reports, duty logs, officer activity records, etc.) and converting these data into the form required for input to the hypercube software (e.g., workload distribution by reporting area, beat configurations, dispatch policies, etc.);
- personnel costs - the manpower costs associated with data collection, hypercube data processing, analysis of hypercube output, and implementation of revised beat configurations and/or revised patrol policies; and
- technical assistance costs - the costs associated with obtaining both initial training in the use of the hypercube system and continuing technical assistance for system usage, interpretation of output, etc.

A. Data Processing Costs

The only data processing costs discussed in this section are those directly related to the use of the hypercube system. These costs include preparation of hypercube input files, use of the hypercube programs to compute performance statistics associated with the beat configuration described in these input files, and retrieval of hypercube output.

Types of Data Processing Costs

The types of data processing costs that may be required to use the hypercube system include the cost of equipment, set-up charges, communications costs, storage charges, and computer usage charges. Each type of change is discussed below.

Equipment. When the hypercube system being accessed is implemented in a time-share or other remote-access environment, a teletypewriter or remote job entry-type terminal capable of both data input and output is required. In addition to the cost of renting or purchasing such a terminal, supplies (such as printer paper) must be purchased, service of the equipment may be required, additional insurance may be needed, and shipping charges associated with obtaining and returning rented equipment will be incurred. Depending on the type of terminal, peripheral equipment may be necessary to provide an interface between the terminal and telephone lines.

Set-up charges. Unless an existing, implemented version of the hypercube system is to be accessed, a number of set-up costs will be incurred before the software can be used. These costs include the following:

- obtaining a copy of the source programs for the version of the hypercube system to be used;
- compiling (translating) these programs into an executable form and testing the programs; and
- developing and testing supporting procedures to facilitate data input, system usage, and output retrieval.

If a commercial data processing system is used, a minimum monthly charge may be imposed by the vendor even if no processing is performed.

Communications costs. When an interactive version of the hypercube system is used on a commercial time-share system, the software and support procedures are usually stored on on-line disk storage devices. In addition, input data used by the hypercube programs are also stored on-line, and in some cases, program output will also need to be stored. Commercial vendors of data processing services usually charge on a daily basis for the amount of storage space used.

Computer usage charges. The data processing costs actually incurred in using the hypercube system depend on the environment in which the system is implemented (e.g., commercial time-share or in-house computer system), the version of the hypercube system being used (e.g., interactive or non-interactive version), and existing department resources (e.g., terminals).

Users of commercial time-share services are billed for the amount of time they are connected to the central site computer, for the amount of computer resources they use in processing, and for the number of input and output operations performed (e.g., the numbers of input records read or output lines printed). Similar charges may also be incurred when data processing is done in a non-time-share environment.

Data Processing Costs Experienced During the Field Tests*

Throughout the hypercube field tests, TIPPA monitored the

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*Costs quoted in this chapter are based on the price schedules of the suppliers of equipment, data processing services, etc. which were in effect in January 1977.

types and amounts of hypercube data processing performed by each of the eight participating departments. The costs experienced by each department are reported in this section, as are costs experienced by TIPPA in making the equipment and software available to each department. The discussion of these costs is presented in two parts. The first describes costs which depend on amount of usage and the size of the problem processed. The second deals with costs which are independent of the level of use or problem size.

Usage-dependent costs. Data processing costs which depended on the amount of computer usage and the size of the regions and beat configurations being analyzed are summarized in Table 3-1 for eight field test cities.* In this table, the regions** that were analyzed are classified as small (100 reporting areas or less), medium (101 to 200 reporting areas), or large (more than 200 reporting areas). Similarly, beat-configurations are classified as small (10 response units or less), medium (11 to 20 response units), or large (more than 20 response units). Iterations refer to the number of times the hypercube software was used to successfully compute performance statistics.

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*In Table 3-1 and throughout the remainder of the chapter, the eight field test cities that used the hypercube system are referred to using alphabetic designators (e.g., "city A").

**A region is defined to be a group of districts (beats) administered as an autonomous field operations territory. Each watch that is analyzed separately with the hypercube software is treated as a separate region. (Thus, if the day, afternoon, and midnight watches are analyzed in one field operations territory, these constitute three analyzed regions.)

Table 3-1

USAGE-DEPENDENT DATA PROCESSING COSTS DURING THE FIELD TESTS

City	Size of Regions	Size of Beat Configurations	Number of Regions Analyzed	Number of Iterations	Storage Costs	Usage Costs	Total Costs
A	large	medium	1	2	$592	$142	$734
B	small	small	3	15	$360	$297	$657
C	small	medium - large	1	4	$360	$358	$718
D	medium	small - medium	1	2	$234	$379	$613
E	small	small	2	16	$164	$451	$615
F	small	small - medium	7	22	$360	$638	$998
G	medium	medium	3	19	$360	$1232	$1592
H	large	medium - large	4	36	$457	$3416	$3863

The cost data in Table 3-1 may not accurately reflect the cost of analyzing and designing beat configurations in all cities of comparable size. Some reasons for cost differences are:

- Most data processing costs during the field tests were borne by TIPPA rather than by the participating departments. As a result, the hypercube users were not particularly concerned with efficient operations to minimize costs. For example, users had the option of running the hypercube program which computes performance statistics either on-line or on a delayed (overnight) basis. Although the costs of overnight runs were only 40 to 50 percent of on-line runs, only cities B and F made extensive use of the overnight capability. Storage costs could also have been significantly reduced by copying data files to tape and releasing the more expensive on-line disk storage during periods of prolonged inactivity. If, for example, this procedure had been used whenever the software was not to be used for two weeks or more, the potential savings in storage charges would have been between 44 percent (city G) and 83 percent (city A).

- Initially, certain operating problems were experienced in using the hypercube software on the National CSS system. These problems involved determining the amount of core storage required for various hypercube operations, and providing sufficient disk storage space to store hypercube output. Failure to provide sufficient core and disk storage space caused operations to terminate abnormally without producing useful results. Providing excessive amounts of core storage led to unnecessarily large charges for terminal connect time (a component of the computer usage charges directly affected by the core size). These operating problems were corrected during the field tests and should not affect future users.

- During the field tests, each department's usage of the hypercube software was monitored, and duplicate copies of all hypercube output were printed for TIPPA use. Such monitoring produced some overhead costs which will not be incurred by future hypercube users.

- The version of the hypercube software used during the field tests was slightly different from the latest versions available to users. These new versions of the software facilitate several hypercube operations. This should contribute to a reduction in hypercube usage costs. On the other hand, more core storage is required to use the hypercube program which interactively creates the input file describing the beat configuration. This may cause an increase in the cost of terminal connect time.

- All departments participating in the field tests used an interactive version of the hypercube software implemented on a commercial time-share system. This is probably the most expensive environment in which the software can be used. Less expensive (and usually less convenient) methods for performing certain hypercube operations, such as the creation of input files, were developed and documented during the field tests, but no cost data for their usage are available. In addition, non-interactive versions of the hypercube software are available which some police departments may be able to implement and use on their own data processing systems for a fraction of the cost of using a commercial system.

- Some features of the hypercube system were not available to the field test participants and, as a result, the costs associated with using these features are not known. These features include variable unit service times, dispatching using automatic vehicle locator systems, and exact computation of performance statistics. (The hypercube model used during the field tests utilized an approximation procedure capable of producing results within a few percent of the exact procedure.) Future hypercube users who utilize any of these features in analyzing medium or large beat configurations can expect to experience significantly higher computer usage costs.

Table 3-2 illustrates how these factors affected the data processing costs incurred in city H. Under ideal conditions, city H could have performed the same hypercube analyses for $1950, or 50 percent less than the actual cost. A police department faced with the same beat design problem in a city of comparable size would probably incur data processing costs between the two costs cited above (i.e., between $1950 and $3863).

Usage-independent costs. The portable teletypewriter terminals used by the eight departments throughout the field test program were rented for a montly cost of $150; non-portable terminals are available for approximately $75 to $125 per month

Table 3-2

POTENTIAL COST REDUCTIONS IN CITY H'S HYPERCUBE ANALYSES DURING THE FIELD TEST

	Cost Incurred During Hypercube Field Test	Minimal Cost of Performing the Same Hypercube Analyses
On-line computation of performance statistics	$1089	$490[a]
Storage of on-line data files	457	202[b]
Abnormally terminated hypercube operations	407	0
Unnecessary terminal connect charges	100	0[c]
TIPPA monitoring of data processing	175	0
Duplicate copies of hypercube output	170	0
Operations not required in latest versions	207	0
Other usage-dependent data processing costs	1258	1258
TOTAL	$3863	$1950

[a]Assumes that 33 hypercube analyses are run overnight, rather than on-line.

[b]Assumes that all data files are erased and on-line disk storage space is released when all analyses are completed.

[c]Assumes that all operations are performed in the minimum amount of core storage required.

depending on the features included and the length of the rental period. Non-portable terminals were not used in the field tests because the terminals were shared among the participating departments. The terminals used in the field tests were available for a minimum rental period of three months. Other terminals may be available for shorter periods at a slightly higher cost. Teletypewriter terminals can also be purchased for between $1,500 and $3,500.

The cost of shipping the terminals to and from the supplier was approximately $50 per terminal. (This cost varies depending on terminal weight and the location of the terminal supplier and the user.) For terminal users located in areas where the supplier maintained a service center, terminal service was provided at no additional cost as part of the rental agreement. Users in other areas were usually required to ship a terminal needing repair to the nearest service center, or pay travel expenses (e.g., $0.75 per mile outside of the normal service area) for an on-site service call. (During the field tests, three of the four heavily used terminals required no service and the fourth required two service calls.) The only terminal supplies required during the field tests was printer paper costing $63 per case of 12 300 foot rolls. A single case of paper was sufficient for the combined data processing of the eight departments.

The cost of obtaining a tape copy of the hypercube system was $40. The cost of program compilations on the National CSS time-share system was approximately $375. Minimum monthly charges were not a factor during the field tests because all data processing was done on a single account, and monthly billings always exceeded NCSS's $100 monthly minimum. Even if each field test department had done its data processing on its own account, only city E would have incurred any minimum charges. All of the field test departments except Fresno were able to access the National CSS system through either a local or toll-free telephone number. Hypercube users in Fresno accessed the system by telephoning Sunnyvale, California, incurring long distance communications costs amounting to approximately $600 over the life of the project. (Fresno was connected to NCSS by telephone for approximately 40 hours during the field tests.)

The cost of storing the hypercube programs and all support procedures facilitating system usage was approximately $88 per month. The cost of storing input and output files varied considerably by department since the costs are dependent on the size of the files (which depends in turn on the numbers of reporting areas and patrol units being analyzed), and on the maximum number of output files stored simultaneously. By deleting files from storage after obtaining paper listings, the field test departments which analyzed small regions and beat plans averaged storage costs of approximately $44 per month, while departments analyzing medium and large regions and beat plans required storage that averaged $66 and $110 per month, respectively.

Usage-independent data processing costs incurred during the field tests are summarized in Table 3-3.

Estimating the Data Processing Costs of Using the Hypercube System

To estimate the data processing costs associated with use of

Table 3-3

USAGE-INDEPENDENT DATA PROCESSING COSTS

1.	Equipment costs	
	a. Terminal purchase	$1500 - $3500
	b. Terminal rental	$75 - $150 per month
	c. Shipping	$40 - $60
	d. Terminal service	$30 per servicing
	e. Terminal supplies	$55 - $70
2.	Set-up costs	
	a. Copy of hypercube software	$50 - $200
	b. Program compilations	$400 (maximum)*
	c. Development of facilitating procedures	$50 - $150
	d. Testing	$50 - $100
	e. Monthly minimum charges	$100 per month*
3.	Communications costs	Depends on user's location
4.	Storage	
	a. Hypercube software	$88 per month*
	b. Input and output files	$44 - $110 per month*

*Based on National CSS rate schedule in effect January 1977.

the hypercube system, the following information must be obtained:

- Number of regions to be analyzed - the number of autonomous field operations areas and watches to be analyzed.
- Size of each region and the corresponding beat configuration - the number of reporting areas in the region, and the number of response units to be represented in the region's beat configuration.
- Maximum number of iterations to be attempted for each region - the number of different sets 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.
- Version of hypercube system to be used and method of operation - whether the software is to be used in a time-share or in-house environment, whether it is to be used on the NCSS or some other commercial time-share system, whether an interactive or non-interactive version of the hypercube system is to be used, whether the hypercube's exact procedures will be required, and whether overnight or immediate turnaround will be required.

Once this information is available, the usage-independent data processing costs can be estimated by identifying those costs (use Table 3-3) that will be applicable. For example, a department planning to use a portable teletypewriter terminal rented for a two month period from a supplier with a local service center to access the hypercube software toll-free through the NCSS system would estimate its usage-independent data processing costs as $876 by summing items 1-b (two months), 1-c, 1-e, 2-a, 4-a (two months), and 4-b (two months):

2 x (150) + 60 + 70 + 50 + 2 x (88) + 2 x (110) = $876.

Estimation of computer usage costs is more difficult. Depending on the version of the software to be used, computer usage will involve one or more of the following steps:

- Creation of an input data file (termed a region file) describing the geography and relative workload of each reporting area in the region - such a file must be created for each region to be analyzed.
- Creation of an input data file (termed a district plan file) describing the beat configuration and patrol policy - such a file must be created for each hypercube iteration in each region.
- Computation of performance statistics corresponding to a specific region and district plan file - such computations are required for each hypercube iteration in each region.
- Retrieval of hypercube output - also required for each hypercube iteration in each region.

Using data processing cost data gathered throughout the field test project, estimates of the costs involved in a single application of each of these phases have been derived. In general, the costs depend on the number of reporting areas in the region, the number of units represented in the district plan, and the number of different workload levels (call rates) for which performance statistics are computed. These estimates are summarized in Tables 3-4 through 3-7.

Table 3-4 contains the estimated cost of creating a region file by entering both geographic and workload data for each reporting area in the region. Table 3-5 can be used to estimate the cost of creating a region file by modifying the workload data in an existing region file without changing the geographic data. The costs of creating a district plan file, computing performance statistics, and retrieving output have been combined into a single estimate described in Tables 3-6 and 3-7. The cost estimates in

Table 3-4

ESTIMATED COST OF CREATING AN INPUT FILE
DESCRIBING REGION GEOGRAPHY AND WORKLOAD*

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

*For example, the cost of creating a region file with 125 reporting areas is approximately $20.

Table 3-5

ESTIMATED COST OF MODIFYING AN EXISTING INPUT FILE
DESCRIBING REGION GEOGRAPHY AND WORKLOAD*

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	19.00	20.00

*For example, the cost of modifying an existing region file with 125 reporting areas is approximately $12.

Table 3-6

ESTIMATED COST OF ONE ON-LINE HYPERCUBE ITERATION (ONE WORKLOAD LEVEL)*

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

*For example, the cost of one on-line hypercube iteration for a region with 150 reporting areas and 10 units is approximately $29.

Table 3-7

ESTIMATED COST OF ONE BATCH HYPERCUBE ITERATION
(ONE WORKLOAD LEVEL)*

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

*For example, the cost of one batch hypercube iteration for a region with 150 reporting areas and 10 units is approximately $20.

Table 3-6 are applicable when performance statistics are computed on-line for a single workload level, while those in Table 3-7 apply when performance statistics are computed off-line (i.e., overnight).

The following items should be considered when attempting to use these cost estimates to predict the data processing costs for future hypercube analyses:

- The estimates were derived assuming that costs increase linearly with the numbers of reporting areas, districts, and workload levels. This assumption appears to hold fairly well for the problem sizes reported in the tables, although the estimates appear to be slightly low for the smaller problems and slightly high for the larger problems (i.e., in the upper left and lower right portions of the tables, respectively).

- The estimates assume that all district plan files are created 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 were based on the rate schedule in effect in January 1977 on the National CSS time-share system. Costs based on different time-share systems are not predictable with the estimates shown in Tables 3-4 through 3-7.

- 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.

As an example in estimating usage-dependent data processing costs, suppose that a department uses the interactive version of the hypercube software implemented on NCSS to design a new beat plan with 10 units for each of three watches in a region containing 150 reporting areas. Suppose also that the department has three alternative beat configurations to be analyzed for each watch in addition to the current plan, that the approximate

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hypercube model is used, and that the department is interested in only one workload level. Since one calibration run will also be required, a total of 15 hypercube iterations will be made (i.e., five for each watch). According to Table 3-6, each iteration will cost approximately $29 if performance statistics are computed on-line. Thus, the total cost for all iterations would be approximately

$$15 \times 29 = \$435.$$

If performance statistics were computed off-line for all iterations, the expected cost would be approximately $300. In addition, a region file would have to be created for one of the watches at an approximate cost of $23 (see Table 3-4). This region file could then be modified for the other two watches at a cost of

$$2 \times 13 = \$26.$$

(see Table 3-5). Thus, the total estimated cost for usage-dependent data processing when performance statistics are computed on-line would be

$$435 + 23 + 26 = \$484.$$

Applying an overhead factor of, say, 1.5 would increase this estimate to

$$1.5 \times 484 = \$726.$$

Combining this with the previous sample estimate of usage-independent data processing costs gives an overall cost estimate of

$$876 + 726 = \$1,602.$$

B. Personnel Costs

The results of the hypercube field test project indicate that departments may 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;
- accessibility of data required to use the hypercube model;
- accessibility of data processing services; and
- extent of cooperation and communication between personnel responsible for the design, approval, and implementation of the new beat plans.

Table 3-8 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 total elapsed time may range from 8 to 28 weeks for a complete beat design effort. It should be noted, however, that 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

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

Table 3-8

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 of 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.

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.

It should be noted that despite their involvement in the field test project, the participating police agencies represented a wide variety of operating and management philosophies, and did not collectively represent a group of departments that could be fairly characterized as more or less advanced than most other police agencies in the United States. As such, the personnel costs identified for the field test agencies should be representative estimates for most police departments.

C. Data Collection Costs

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 time estimates can be significantly enhanced if a data assessment is made during the initial planning stages of the project. 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 procedure 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 3-9 summarizes the number of man-weeks spent by the departments in the field test project to collect data for the hypercube programs. Five of the eight departments required from one to four man-weeks. The three departments requiring more than four man-weeks utilized several coders for two to three weeks to extract data from department files. The eight field test departments utilized an average of 4.6 man-weeks for data collection activities. Despite considerable differences in department size, no significant relationship between the amount of data collection effort and department size was noted for the field test agencies. Although larger departments will necessarily require more data in order to adequately describe the geographic distributions of

Table 3-9

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

workload over several precincts or districts, these are, very often, the same departments that have access to more sophisticated data processing facilities to help in the collection and preparation of the input data.

It should also be noted that data collection involves not only extracting raw data from department files, but also translating this raw data into hypercube-usable form. This additional processing may require considerable personnel time and data processing activities. The Institute for Public Program Analysis helped several of the field test departments with data preparation during the field test project. The man-weeks expended by Institute staff for data preparation are not included in the estimates shown in Table 3-9.

The experience of the Institute staff suggested that careful use of any one of a number of widely distributed statistical packages such as SPSS, SAS, BMD, and OSIRIS can appreciably reduce the time and effort required to aggregate, screen, and summarize large amounts of raw data into useful input data sets.

D. 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. A list of these documents is presented in Appendix C. 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.* Such formalized training in a classroom setting is available from several agencies identified in Appendix C. Only The Institute for Public Program Analysis offers more than a one- or two-day introduction in the use of the system. Tuition for these courses is usually between $300 and $600 per person. 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 to use the hypercube system by trial and error can 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. Agencies should find self-training an acceptable alternative to formalized training as more documentation of the hypercube system becomes available.

Some departments may want to use knowledgeable persons from outside the department to assist in some of the major tasks of a

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*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.

beat design project. Agencies from which such technical assistance can be obtained are identified in Appendix C. Agencies such as The Institute for Public Program Analysis provide a limited amount of 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 sources.

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 3-10.

Table 3-10

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 Per Department
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.

CHAPTER IV

ASSESSMENT OF THE HYPERCUBE PROGRAMS AND MODEL

The purpose of this chapter is to assess (1) the usability of the hypercube software, (2) the content and format of the hypercube output, and (3) the accuracy of the performance estimates produced by the hypercube model. Improvements made to the hypercube programs by TIPPA and the M. I. T. research team during the field test project are summarized, and recommendations for additional changes to the software are identified.

A. Assessment of the Software

The hypercube software has undergone a number of major revisions during the field test project. In May 1975, the hypercube system consisted of:

- an interactive program, termed "MONITOR" by its M. I. T. developers, which is used to create a data file (termed the district plan file) describing the basic features of a patrol policy and beat configuration;
- a program "HYPOPT" used to compute region, unit, and district performance statistics associated with the district plan file created by the "MONITOR" and a second input file (termed the region file) containing certain geographic data; and
- a program "HYPERCUBE" used to compute region, unit, and district performance measures, as well as numerous other statistics, associated with a single input file containing district plan and region data.

The "MONITOR" and "HYPOPT" programs were originally developed as training tools for introducing new hypercube users to the input data required for computerized beat design and the interpretation of hypercube output. The "HYPERCUBE" program with its advanced features was intended for users knowledgeable in the process of analyzing and/or redesigning beat configurations and patrol policies. Unfortunately, the format of the district plan file created by the "MONITOR" was not compatible with the input file required by the "HYPERCUBE" program. Thus, the "HYPERCUBE" program could not be easily employed by users familiar with only the "MONITOR" program. In addition, the advanced features required to model actual police patrol operations (and only available with the "HYPERCUBE" program) were not supported by the "MONITOR" and "HYPOPT" programs.

As a result, TIPPA developed a modified hypercube system prior to the beginning of the actual field tests in June 1976, consisting of

- the interactive "MONITOR" program for creating district plan files;
- a "TRANSLATE" program to convert a "MONITOR" district plan file and a region file into a single input file usable with the "HYPERCUBE" program; and
- the "HYPERCUBE" program for computing performance statistics.

Changes identified by TIPPA during previous tests of the M. I. T. hypercube system were incorporated into these programs, and procedures for facilitating their use, the creation of region files, and the retrieval of output were developed for the NCSS time-share system.

Coincidentally, the M. I. T. research team developed an advanced hypercube system featuring:

- an interactive "MONITOR" program supporting most advanced features of the "HYPERCUBE" program; and
- an advanced "HYPERCUBE" program capable of using a region file and a district plan file created by the

"MONITOR" as input, and supporting additional features of patrol operations (notably dispatching with automatic vehicle locators).

This version of the hypercube system was subsequently tested by TIPPA, changes were suggested to the M. I. T. research team, and a modified version incorporating many of the changes was implemented on NCSS.

As a result of these continuing software revisions, many problems were identified and corrected, numerous improvements were made, and several new features were added. These changes make the latest versions of the hypercube system much easier to use. Significant changes made during the field test project by TIPPA, the M. I. T. research team, and M. I. T. personnel working as consultants to TIPPA include:

- A number of limitations on the size of problems that could be analyzed with the hypercube software have been relaxed. For example, beat configurations with up to 34 units can now be analyzed (the previous limit was 15), and all restrictions on the number of reporting areas in a region (previously limited to 200) have been removed.

- Restrictions on input data have been eased. For example, reporting areas need not be sequentially numbered, reporting area identifiers can contain up to six digits (rather than three), and the (x, y) coordinates of reporting area centers can be specified using any convenient unit of measure (rather than units of 100 feet).

- Terminology used in the original "MONITOR" program has been modified for clarity and compatibility with "HYPERCUBE" documentation and output. For example, the terms "patrol unit speed" and "patrol speed" have been replaced by "response speed" and "preventive patrol speed;" the input file containing geographic data is now referred to as the "region file," rather than "city file;" and patrol areas are now termed "districts" rather than "sectors" or "beats." In addition, an optional explanation of the terminology used in the "MONITOR" to refer to response units, calls for service, etc. can be printed at the user's terminal; and, the user can modify the terminology used in the hypercube output.

- References within the output of the "MONITOR" to M. I. T. technical report "TR-14" which serves as the "HYPERCUBE" user's manual have been replaced by references to the more widely distributed edition of the report, "Hypercube Queuing Model: User's Manual," available from The Rand Corporation as R-1688/2-HUD.

- Some output formats have been modified. For example, "HYPERCUBE" output was originally intended to be listed on a line printer capable of printing at least 100 characters per line. As a result, some tables were virtually unreadable when the output from beat configurations with more than seven or eight units was printed on a teletypewriter terminal limited to 80 characters per line. These tables have been reformatted so that all lines contain 80 characters or less, and all columns in the tables are aligned. While the output becomes somewhat longer when listed on a line printer, it is readable when listed on any terminal, regardless of the number of units used. Also, the actual reporting area identifiers, rather than a simple sequential numbering, are now printed in the table showing the distribution of calls for service by reporting area.

- The user has more flexibility in specifying the amounts and types of output produced. The user can specify which tables, if any, are to be produced in addition to those containing region, unit, and district performance measures. Alternatively, users of the hypercube system implemented on NCSS can specify that all output tables are to be produced, and then selectively print and examine a few tables before deciding whether to print the other tables.

- Procedures for specifying overlay districts have been simplified. Earlier hypercube systems were somewhat inconvenient to use when the districts to be specified overlapped and there were many reporting areas in the region. This resulted because (1) to define a district which overlaid two or more other districts, the identifier of each reporting area in the overlaid districts had to be keyed in a second time at the terminal, and (2) as part of the "MONITOR" program's error-checking capabilities, reporting areas appearing in more than one district were listed. Such a listing was time-consuming to produce, and often annoying to users already aware of the overlap. In the latest versions of the hypercube system, overlay districts can be specified by simply inputting the numbers of the overlaid districts--not the identifiers of their reporting areas. If districts overlap, the user is still notified, but the listing of reporting areas in more than one district is now optional.

- Additional error-checking capabilities have been included. Individual data items entered by the user are checked to ensure that they are valid within acceptable ranges, and are cross-checked against previously input data items to ensure that conflicting or inconsistent features are not specified in the district plan. In some cases, the user is simply notified of the conflict. In other cases, the conflict is resolved internally by modifying one of the conflicting features, and then notifying the user of the action taken. For example, the approximate model cannot be used when either variable unit service times or AVL (automatic vehicle locator) dispatching is used; first, last, or middle dispatch preferences cannot be specified for particular units in selected reporting areas when AVL dispatching is used; and the combination of the number of units, average service time, and call arrival rate cannot be such that utilization (i.e., the fraction of time, on the average, that units are busy handling calls for service) is greater than 1.0 if arriving calls are queued when no unit is available. While not an error, a warning is also printed whenever the user specifies that the exact hypercube model is to be used in performing the computations because of the greatly increased cost and core storage requirements.

- No currently available versions of the hypercube system adequately model multiple car dispatching or non-call-for-service workloads. Consequently, users wanting to account for this workload in computing performance statistics can do so only by inflating the call arrival rate. A procedure has been added to the "MONITOR" program which will compute the appropriate inflated call rate from user-supplied data on the fraction of calls requiring two (or more) units, the average service time for the second (and subsequent) dispatched unit(s), and the average amount of time per hour units spend on non-call-for-service activities.

- Intermediate district plan files can now be saved before they are completely specified. This provides a safeguard against any abnormal termination of the "MONITOR" program which would otherwise cause all data previously entered into the file to be lost. These intermediate files are also periodically saved during a terminal session with no explicit action on the part of the user required.

- Previous versions of the "HYPERCUBE" program required that reporting areas referenced internally in the input file be designated by a sequential numbering scheme. The latest version uses actual reporting area identifiers to specify most features internally in the file. While this change is transparent to users who create this file using the "MONITOR" program, it greatly facilitates independent file creation and modification.

The result of these many changes is a hypercube system that is quite flexible and usable within the following constraints:

- While basic features of a district configuration and patrol policy can be specified by novice users relying on the interactive "MONITOR" program's tutorial capabilities, the use of the "MONITOR" program's advanced features, specification of district plans without the use of this program, and interpretation of hypercube output require a more sophisticated user who is familiar with the input formats of commands, and the structure of data files. Such sophistication in turn requires good software documentation, and a time investment by the user to familiarize himself with the documentation before attempting to utilize the system.

- For problems with large numbers of reporting areas in the region of interest and units in the district configuration, the software requires large amounts of core storage.

- The hypercube system can be expensive to use, especially when implemented in a commercial data processing environment (cost factors are discussed in Chapter III).

To make the software more usable, the following changes are recommended for incorporation in future revisions of the software:

- Additional output statistics could be produced from available data without greatly increasing the total amount of calculations. These statistics include the average length of time queued calls for service are held by the dispatcher in waiting for a response unit to become available (queuing delay), the average response time (i.e., the sum of queuing delay and travel time) to calls for service by region, district, and reporting area, and the size (e.g., the square mile area) of each district.

- Some hypercube output tables would be more useful if they were reformatted. For example, the tables containing reporting area specific performance measures would be easier to use if all reporting areas contained in the same district were grouped together, with reporting areas in more than one district flagged in some way, rather than having the reporting areas listed in numerical order.

- Better labelling of hypercube output tables is also recommended. Specifically, the title of the run should appear on every table, and all input parameters (e.g., response speeds, the scaling factor used to adjust coordinate data, and the constant of proportionality used to compute intra-reporting area travel times) should appear in the output.

- A glossary capability, whereby the user of the "MONITOR" program could specify the terminology to be used during the terminal session to refer to response units, calls for service, etc., could be added. In addition, some technical terms appearing in the hypercube output (e.g., "infinite line capacity," "spatial allocation," and "probability of saturation") should be replaced by terminology more familiar to police users.

- Tutorial capabilities of the "MONITOR" program should be expanded. At a minimum, some information should be available to users of advanced hypercube features, describing command formats and the use of each feature. This would reduce the need to refer to user's manuals during a terminal session (an expensive process). These capabilities could be further expanded by allowing the user to determine the amount of detail to be included in printed explanations.

- Additional options for specifying the relative amounts of preventive patrol in each reporting area could be implemented. (Currently, the user must specify either that preventive patrol in each reporting area is proportional to that reporting area's workload, or a preventive patrol factor for each reporting area in the district.) For example, options could be included to specify that preventive patrol is uniform among the reporting areas of the district, or is proportional to workload except in a specified list of reporting areas which would have user-supplied preventive patrol factors. Also, the user should be able to request a listing of the preventive patrol factors used when patrol factors proportional to workload are specified.

- Current versions of the "HYPERCUBE" program require that call volume data appear in fixed positions (columns) of each record of the region file. By allowing the user to specify where this data item appears in the file, up to six different sets of call volume data could be included in a single region file with 80 character records. This would eliminate the need to store separate region files containing identical geographic data and different call volume data.

- In the current version of the "HYPERCUBE" program, performance statistics computed when districts overlap and the district-unit-first dispatching policy is used, are affected by the order in which the districts are defined in the district plan file. As a result, different statistics can be produced by files which have the same district configuration and patrol policy, but district definitions appear in different orders. The program should be changed to eliminate dependence of the statistics on the order in which districts are defined.

- The "HYPERCUBE" program should be changed to accept actual reporting area identifiers, rather than an arbitrary (i.e., sequential) numbering whenever reporting areas are referred to in the input file.

Additional capabilities which are absent in the current versions of the software, but would be useful to police users, include the following:

- More precise methods for dealing with patrol initiated and other non-call-for-service workloads should be developed and incorporated into the hypercube software.

- A method for dealing with calls for service falling into two or more priority classes should also be developed since this is a factor in the dispatching procedures of virtually all police departments.

- Prescriptive capabilities, whereby the "HYPERCUBE" program would suggest alternative district configurations to improve or "optimize" a particular performance measure (e.g., to reduce workload imbalances, travel time imbalances, or cross-district dispatches), would be useful to police departments which want to redesign district plans on the basis of a single performance criterion.

These capabilities, however, would also be of use to users in general since they would enable a designer to determine the best values of the performance measures attainable in the region being analyzed. The designer could then compare these optimal values to those for his own plans and decide, for example, whether further improvements are possible.

B. Assessment of the Hypercube Performance Estimates

Introduction

The usefulness of the hypercube model as an aid in evaluating alternative patrol plans and policies depends upon its ability to accurately forecast patrol performance characteristics with user-supplied data. Accordingly, one objective of the field test project was an assessment of the accuracy and usefulness of field performance estimates generated by the model. This section describes the assessment activities and results.

The major questions addressed by the assessment include the following:

- How accurate are hypercube estimates of regionwide, beat, and unit level performance measures?
- How sensitive is the model to input data based on limited field data?
- How much input data are needed to adequately describe the geographic and operational characteristics of a region and patrol plan?
- What type of planning questions can the model best answer?

In addition to providing a framework in which the strengths and weaknesses of the model could be identified, assessment activities also provided additional insights into:

- data collection problems and strategies,
- input data modifications to compensate for model limitations, and

- the appropriate use of the model for evaluating alternative patrol policies.

The assessment consisted of two kinds of investigation: a technical assessment based on a comparison of hypercube estimates with empirical data collected from police departments participating in the field test project, and an implementation assessment based on the use of the hypercube model by planners in the test agencies.

Comparison Variables

The comparison of performance estimates from a single run of the hypercube model with empirical results is not an easy task. The hypercube model produces more than 20 estimates of workload, travel time, and cross-beat dispatching at the region, unit, beat, and reporting area levels (see Table 4-1). The field test project did not attempt to validate all of these estimates. Rather, the assessment was directed at verifying the accuracy of eight hypercube estimates of workload, travel time, and cross-beat dispatching at the region, beat, and unit levels (see Table 4-2).

Other hypercube estimates were not included in the assessment for the following reasons:

- No estimates for measures at the reporting area level were examined because the volume of field data required to obtain reliable empirical statistics could not be obtained from any field test agency with the resources of the project.

- Hypercube estimates of beat workloads were not examined since they are merely the sum of the workloads input by the user for each reporting area in the beat.

- Regionwide travel time was not used as a comparison variable since none of the field test agencies had reliable information about the average speed of units responding to dispatched assignments.

- Regionwide utilization was not examined because both empirical and hypercube estimates of utilization are determined in the same manner from the call rate, service time, and number of patrol units input by the user.

Table 4-1

PATROL PERFORMANCE STATISTICS ESTIMATED BY THE HYPERCUBE MODEL

	Level			
	Region	Unit	Beat	Reporting Area
Workload Estimates	• Avg. unilization/ unit • Avg. workload/ unit • Stan. dev. of the unit work-loads • Max. unit work-load imbalance • Probability of saturation	• Workload/unit • Pct. of the avg. workload/unit	• Workload/beat • Pct. of the avg. workload/beat	• Workload/r.a. • Workload/r.a./ unit
Travel Time Estimates	• Avg. travel time/ call • Avg. travel time/ queued call	• Avg. travel time/ call/unit	• Avg. travel time/ call/beat	• Avg. travel time/call/r.a. • Avg. travel time/call/ unit/r.a. • Avg. inter-r.a. travel time/call
Cross-beat Dispatching Estimates	• Fraction of calls requiring cross-beat response	• Fraction of cross-beat calls/unit • Pct. of avg. cross-beat fraction/ unit	• Fraction of cross-beat calls/beat • Pct. of avg. cross-beat fraction/beat	

Table 4-2

HYPERCUBE PERFORMANCE ESTIMATES EXAMINED FOR THE FIELD TEST PROJECT ASSESSMENT

Level	Performance Estimate	Comparison Measures
• Region	• Avg. workload/unit • Fraction of call requiring cross-beat response • Probability of saturation	• Difference • Percent difference
• Unit	• Workload/unit • Avg. travel time/call/unit* • Fraction of cross-beat calls/unit	• Average absolute difference • Average absolute percent difference
• Beat	• Avg. travel time/call/beat* • Fraction of cross-beat calls/beat	• Sum of the absolute rank differences

*Travel times for each unit and beat are calculated using response speeds calibrated so that region travel time estimates produced by the hypercube model equal average region travel times based on empirical data.

Comparison Measures

The measures that were used to quantify the differences between each hypercube estimate and the corresponding empirical statistic for each variable identified above are also shown in Table 4-2. Two sets of measures were used: one for comparing regional estimates, and another for comparing beat and unit level estimates.

Measures at the region level were compared by calculating the absolute and percent differences between corresponding hypercube and empirical values. As an example, sample hypercube and empirical data for three region level variables are shown in Table 4-3. The absolute and percent differences for each variable indicate excellent agreement (in this example) between the hypercube and empirical results.

Unit and beat level measures were compared by aggregating the hypercube and empirical results for each unit or beat into cumulative

Table 4-3

A SAMPLE COMPARISON OF REGION LEVEL HYPERCUBE ESTIMATES AND EMPIRICAL STATISTICS

Comparison Variable	Empirical Statistic	Hypercube Estimate	Difference	Percent Difference
Average Work-load/Unit	0.570	0.564	0.0060	1.05
Probability of Saturation	0.0588	0.0573	0.0015	2.55
Fraction of Cross-Beat Dispatches	0.493	0.483	0.0100	2.03

measures. Three aggregate measures were used:

- the average absolute difference between each hypercube and empirical measure,
- the average absolute percent difference between each hypercube and empirical measure, and
- the sum of the absolute rank differences between each hypercube and empirical measure.

Calculation of each measure for sample travel time data for a nine-unit patrol plan is illustrated in Table 4-4. The average absolute difference in travel time for the nine units is 0.868 minutes or 52.08 seconds. This is equivalent to an average absolute percent difference of 10.39 percent.

It should be noted that the average absolute difference and average absolute percent difference measures represent an unweighted average of the nine-unit value (i.e., these measures do not take into account that some units may have more calls for service than others). Unit workloads could have been used to weight the travel time estimates for each unit. Weighting beat and unit comparison measures for travel time and cross-beat dispatching by unit workload was not used for the assessment for the following reasons:

- Since the hypercube model does not explicitly recognize non-patrol time spent on administrative activities, all of the hypercube runs for the assessment included this time by inflating the call-for-service rate. As a result, workload estimates for each unit included time for administrative activities for which hypercube travel time and cross-beat dispatching estimates may be highly inappropriate. Since administrative workload may represent from 10 to 75 percent of a unit's total workload, the use of unit workloads to weight unit and beat estimates is questionable.
- Assessment activities indicated that for most empirical beat configurations and workload distributions weighting the unit or beat differences produces only slight changes.

Table 4-4

SAMPLE COMPARISON OF HYPERCUBE ESTIMATES AND EMPIRICAL STATISTICS FOR UNIT TRAVEL TIMES BASED ON A NINE-UNIT PATROL PLAN

Unit	Empirical Travel Time (min.)	Hypercube Travel Time* (min.)	Absolute Difference (min.)	Empirical Rank	Hypercube Rank	Absolute Rank Difference
1	9.810	9.049	0.761	2.0	2.0	0.0
2	5.440	7.060	1.620	9.0	4.0	5.0
3	5.550	7.586	2.036	8.0	3.0	5.0
4	11.620	9.842	1.778	1.0	1.0	0.0
5	5.680	5.684	0.004	6.5	6.0	0.5
6	5.680	5.680	0.000	6.5	7.0	0.5
7	6.500	5.647	0.853	3.5	8.0	4.5
8	6.500	5.640	0.860	3.5	9.0	5.5
9	6.290	6.880	0.590	5.0	5.0	0.0
Total	63.070	63.069	7.812			21.0
Average	7.008	7.008	0.868 = 52.08 seconds			

Average absolute percent difference = (0.868 ÷ 7.008) x 100 = 12.386

*Based on a patrol response speed calibrated to match the empirical region travel time.

Empirical and hypercube values for the nine-unit travel times are ranked in Table 4-4 from highest (rank=1) to lowest (rank=9). The absolute difference between the two ranks for each unit is shown in the rightmost column of the table. The sum of these absolute rank differences is 21. The rank sum measure is used to test the ability of the hypercube model to estimate the travel time of each unit relative to all other units--that is, to measure how well the hypercube model predicts the unit with the longest travel time, the unit with the second longest travel time, and so on. The ability of the model to accurately forecast the relative magnitudes of unit and beat variables can be valuable for planning studies even if the absolute accuracy of the unit or beat estimates is in doubt.

The sum of the absolute rank differences can vary from a minimum of zero, when all the ranks agree, to a maximum positive number which depends on the number of units or beats. More precisely, the limits on the sum S are given by

$$0 \leq S \leq \begin{cases} N^2/2, & \text{if N is even} \\ N^2-1)/2, & \text{if N is odd} \end{cases}$$

where N is the number of units or beats. Table 4-5 contains critical values of S for testing the null hypothesis that the hypercube and empirical estimates are not drawn from the same distribution (i.e., that they are not the same). Based on the rank sum for the nine-unit example shown in Table 4-4, the null hypothesis would be accepted since S=21 is not less than or equal to the critical value $S_c(9,.05) = 14$. (If $S \leq 14$, the null hypothesis would be rejected

Table 4-5

CRITICAL VALUES* $S_C(N,\alpha)$ FOR THE SUM OF THE ABSOLUTE RANK DIFFERENCES STATISTIC

N (no. of units or beats)	Significance Level (α)		
	$\alpha = .01$	$\alpha = .05$	$\alpha = .10$
2	None	None	None
3	None	None	None
4	None	0	0
5	0	2	2
6	2	4	6
7	4	6	8
8	6	10	12
9	10	14	16
10	14	18	22
11	20	24	28
12	24	30	34

*If $S \leq S_C(N,\alpha)$, the null hypothesis that the set of ranks for the hypercube estimates is not drawn from the same distribution as the set of empirical rankings is rejected at the α-level of significance.

at the 5 percent level of significance.*) For all of the assessment comparisons described below, the lowest significance level examined is 10 percent (i.e., if the sum of the rank differences is not less than or equal to the critical value at the 10 percent level, it is labeled as "not significant").

Empirical Data Collection

To carry out the assessment activities, it was necessary to collect, in addition to the data required as input to the model, the following data from the field test agencies:

- additional data about empirical workload and performance characteristics at the beat and unit level;
- aggregated data based on tours with the same number of patrol units, the same beat configuration, and the same time of the day; and
- increased amounts of data to obtain accurate estimates of patrol performance and workload distributions.

Despite considerable data collection efforts in several agencies, adequate empirical data for the assessment could only be obtained from the St. Louis County and Pasadena departments. Failure to obtain adequate data from the other field test departments occurred for the following reasons:

- Small data base - Huntington Beach and San Jose participated in the field test project without initiating extensive data collection activities. Since neither department planned to change its beat configuration based on their hypercube analyses, personnel in both departments used small data sets to examine the model.

- Lack of unit and beat information - Although Fresno used the hypercube model to redesign their beat plan during the field

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*The level of significance associated with each critical value indicates the probability of making a wrong decision based on this value (i.e., the probability of incorrectly rejecting the null hypothesis and concluding that the two sets of ranks come from the same distribution). As an example, a critical value with a 5 percent significance level will yield correct decisions 95 percent of the time.

test project, detailed performance data at the unit level, not routinely maintained in their management information system, could not be easily obtained from other department records.

- Absence of consistent data sets - Burbank and Garden Grove obtained their data for the hypercube model by sampling from several months of dispatch records. As a result, their data bases represented patrol performance characteristics from tours with different numbers of patrol units, different beat configurations, and different times of the day. Although the size of the total data base collected for each department was sufficient, subdividing into consistent data sets with the same number of units, beat configurations, and times of day would have produced data bases that were too small for meaningful assessment comparisons.

- Inappropriate data collection base - San Diego, the largest city to participate in the field test project, uses census tracts as the smallest geographic area for recording police workload data and constructing patrol beats. As a result, in some areas of the city, beats contain as few as two or three census tracts. In addition, the amount of data required for San Diego was prohibitively large and no geographic or district barriers existed which could be used to define a smaller area of the city for special data collection efforts.

Assessment Comparisons

The following sections describe the assessment comparisons using data collected from the St. Louis County and Pasadena departments.

St. Louis County. The data base for the assessment comparisons for St. Louis County was derived from 1975 radio tapes. These tapes contain over 685,000 individual records, documented all major communications between patrol units in the field and the department's dispatching center. The major types of records on the tape are:

Type of Communication	Number	Percent
• administrative activities	271,000	39.6
• calls for service	163,000	23.8
• duty logs	100,000	14.6
• self-initiated calls	45,000	6.6
• other	106,000	15.5

To obtain a consistent empirical data base for the assessment, the following requirements were used to define the comparison data base for St. Louis County:

- First Precinct - To obtain a consistent geographic base, only records from the First Precinct were included. The First Precinct was selected because it is the largest and busiest precinct in St. Louis County.

- Day watch - To obtain a consistent temporal base, only records from the day watch were included. The day watch was selected because preliminary information supplied by the Department suggested that there was less variation in the number of units fielded each day than would be found on either the afternoon or night watches.

- Middle six hours of the day watch - To minimize the effects of unit changeovers at the beginning and end of the day watch (7 a.m. - 3 p.m.), records were included from only the middle six hours of the watch (8 a.m.-2 p.m.).

- Uniform number of patrol units - Analysis of the 1975 data for the day watch in the First Precinct revealed variations in the number of units actually fielded each day. The number of units ranged from a low of 7 to a high of 16. The operational plan for the Precinct called for 11 units every day. A breakdown of the number of units fielded is shown below:

Number of Patrol Units	Number of Times During 1975
7	1
8	8
9	18
10	65
11	81
12	91
13	63
14	27
15	5
16	2
Unknown	4
Total	365

To obtain a consistent data base, only records from the 81 tours with exactly 11 patrol units were included. The more common 12-unit tours (91 tours) were not selected since the location of the twelfth unit in the 11-beat configuration of the Precinct tended to vary from tour to tour.

The effect of these requirements on the size of the data base is summarized below:

Requirement	Number of Records in 1975
• St. Louis County	685,475
• First Precinct	122,125
• CFS, self-initiated, and administrative calls only	99,944
• Day watch (7 a.m.-3 p.m.)	31,554
• Middle six hours (8 a.m.-2 p.m.)	24,638
• Eleven-unit tours	5,362

All of the comparisons discussed below for St. Louis County are based on the 5,362 records that satisfied all of the screening requirements. These records plus other information obtained from the department's Planning and Research Bureau were used to calculate empirical results and input values for the hypercube model. These results are summarized below:

- Beat configuration and geographic data - The same 11-beat configuration (see Figure 4-1) was used for all comparisons. The coordinates, area, and beat assignment for each of the 114 reporting areas in the First Precinct were supplied by the Planning and Research Bureau. The number of reporting areas in each beat and resulting beat sizes are indicated below:

Beat	Number of Reporting Areas	Size (Sq. Miles)
101	12	8.61
102	9	17.89
103	7	3.94
104	7	7.33
105	16	5.95
106	9	19.31
107	19	16.18
108	6	16.03
109	6	9.55
110	10	3.47
111	13	11.83
Total	114	120.09

- Service time - Based on 5,183 records (96.7 percent of the total number of records), the average service time per call was 24.62 minutes (see Table 4-6). Service time was determined for each record by taking the difference between time cleared and time

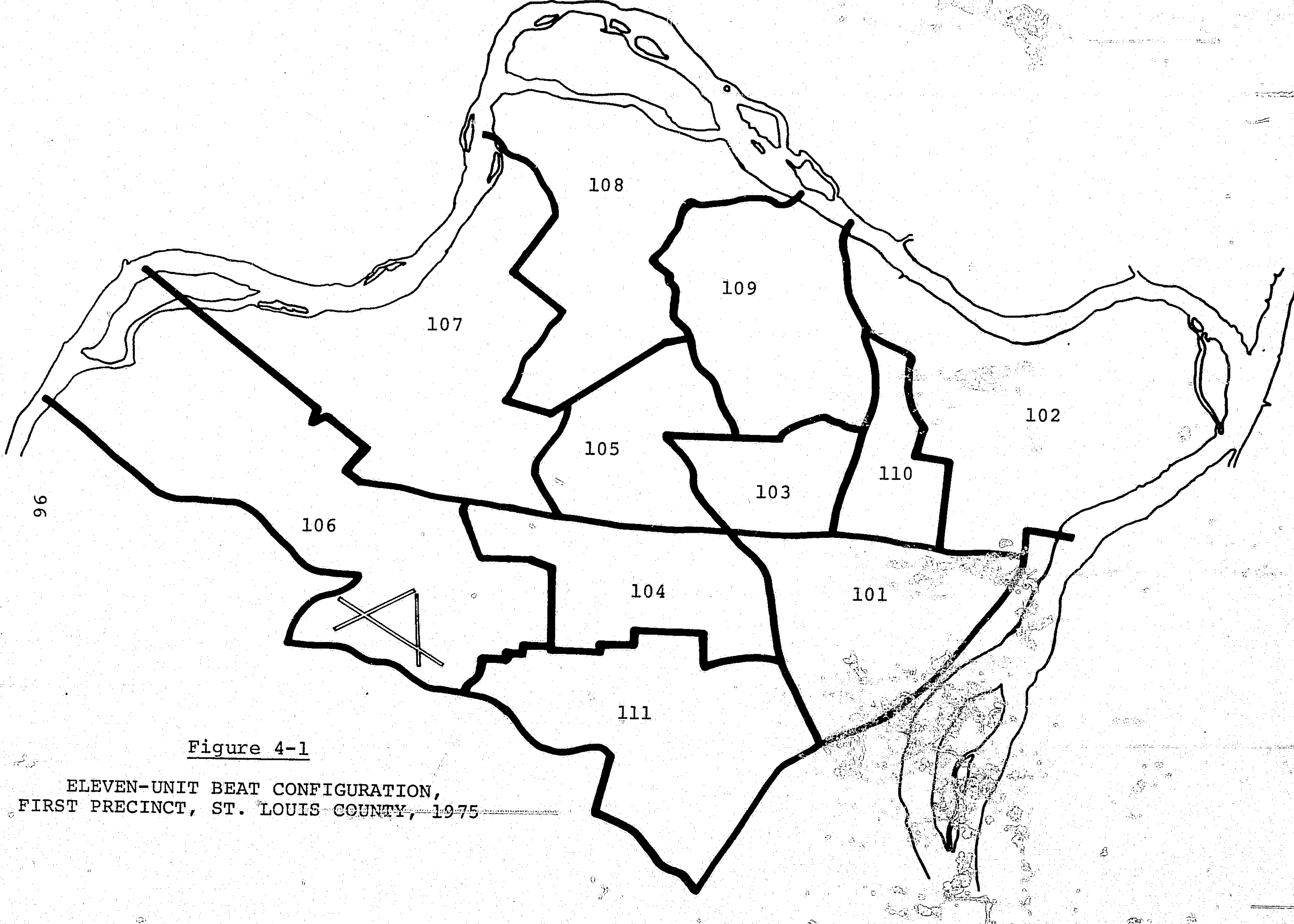

Figure 4-1

ELEVEN-UNIT BEAT CONFIGURATION,
FIRST PRECINCT, ST. LOUIS COUNTY, 1975

Table 4-6

EMPIRICAL PATROL DATA FOR ST. LOUIS COUNTY

	Type of Call		
	Dispatched and Self-Initiated	Administrative	Total
• Number of Incidents	2,836 (52.9%)	2,526 (47.1%)	5,362 (100.0%)
• Number of Service Minutes/Hour	164.1 (57.7%)	120.5 (42.3%)	284.6 (100.0%)
• Service Time/ Call (minutes)	26.95 (N=2,749)	22.00 (N=2,434)	24.62 (N=5,183)
• Call Rate[a]	6.09	5.48	11.56
• Travel Time/ Call (minutes)	7.27 (N=1,464)	b	7.27 (N=1,464)

[a]Call rate equals the number of service-minutes per hour divided by the average service time per call.

[b]Location and arrival time are not routinely recorded for administrative calls.

dispatched. Calls for which either the dispatched or cleared time were missing, or the calculated time was less than zero or greater than 240 minutes were not included. Only 179 (3.3 percent) records were not used for these reasons.

- Call rate - The call rate for the 11-unit configuration was determined by dividing the average number of service minutes per hour for the 11 units by the average service time per call. The value obtained was 11.56 calls per hour (see Table 4-6). Dividing the total number of calls received by the total number of hours should yield the same result under ideal conditions. With this method, the St. Louis County data produced:

call rate = (number of calls)/(total hours)

= (5,362)/(487.35)*

call rate = 11.00 calls per hour.

The difference between the two call rate values is due primarily to the use of slightly different criteria in selecting the service times used to calculate the average service minutes per hour and the average service time per call. If these differences had been eliminated, the new call rate, calculated by dividing total service time per hour by average service time per call, would have been 11.10 calls per hour, a decrease of 4.0 percent from the value used for the assessment comparisons. (The sensitivity of hypercube estimates to changes in the call rate is discussed below.)

- Travel speed - The St. Louis County Police Department had no reliable data on the average speed of patrol units responding to dispatched assignments. In place of an empirical value, a calibrated travel speed, based on travel time data for the entire precinct, was computed. Travel time was defined as the difference between the time arrived and time dispatched. The precinct average of 7.27 minutes was based on 1,464 records. Travel time data for the remaining 3,898 records could not be determined for the following reasons: (1) arrival times are not recorded for administrative calls, (2) many CFS records did not include the unit arrival time, and (3) no travel time was calculated for self-initiated assignments. For the baseline St. Louis County data, the calibrated travel speed was 19.16 miles per hour.

- Dispatch policy - Discussions with personnel in the Planning and Research Bureau led to the adoption of the following dispatching policy:** (1) beat car first, (2) infinite capacity queue, and

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*Records were selected from a period that was 361 minutes in length. Hence, the 81 tours consisted of 29,241 munutes (81 tours x 361 minutes/tour) or 487.35 hours.

**For an explanation of the dispatching options available in the hypercube model, see Instructional Materials for Learning to Use the Hypercube Programs for Analysis of Police Patrol Operations.

(3) MCM selection procedure. To verify the beat car first and infinite capacity queue policies, a manual simulation of the dispatching operation based on 12 hours of records was performed. During the simulation, as each call was received, the unit assigned was checked against all units that were not busy. In 95 percent of the cases (38 out of 40 calls), the dispatcher selected the beat car if it was available. Twice during the simulation, the system was saturated (i.e., all units were busy). The longer dispatching times (i.e., the difference between the time a call was received by the police and the time a unit was dispatched) during the saturation periods suggested that calls were being stacked until one of the 11 beat units was available. This is consistent with the assumptions of an infinite capacity queue. It was noted, however, that calls in the queue were not always assigned to the first available unit. This may have reflected the reluctance of dispatchers to assign units to calls that were 10 or 15 miles away from their assigned beats. Although empirical estimates of the probability of saturation were not available, hypercube results indicated low saturation rates (i.e., less than two percent). The appropriateness of the MCM unit selection policy is discussed below.

- Preventive patrol policy - Other than the general requirement that each unit remain in its assigned beat while on preventive patrol, the St. Louis County Police Department had no fixed preventive patrol policy, and maintained no records on the location of field units that were not on an administrative or dispatched assignment. Department personnel felt that, in general, beat units did patrol the higher workload reporting areas in their beats more frequently, and recommended that, for the hypercube analysis, preventive patrol activity in each reporting area be treated as proportional to the workload distribution.

- Geographic workload distribution - Determination of an appropriate workload distribution for the First Precinct was difficult because (1) department records did not indicate either the beat or reporting area for administrative calls, and (2) there was considerable variation in the average service time among the 11 beats. The absence of geographic data for administrative calls was significant since administrative workload represented 47 percent of the calls and over 42 percent of the total workload. Three options were considered for distributing the administrative calls: (1) distribute administrative calls over the reporting areas for the entire precinct in the same proportion as dispatched and self-initiated workload,* (2) distribute administrative calls for each unit among the reporting areas in that unit's beat in proportion to the distribution of all dispatched and self-initiated calls among the reporting areas in the beat, and (3) place all administrative calls for each unit in an artificial reporting area located

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*Since this option merely inflates the number of dispatched and self-initiated calls in each reporting area by a constant factor, the dispatched and self-initiated call distribution could be used without modification.

in the center of the unit's assigned beat. The second option was used for the assessment comparisons. The effects of using each option are discussed below.

Since the hypercube model uses the same service time distribution for every call, the model bases the relative workload for each beat on the total number of calls listed for each reporting area in the input data file. If, however, empirical service times vary considerably from one beat to another, the hypercube model will overestimate the workload for beats with lower than average service times and underestimate the workload for beats with higher than average service times. In St. Louis County, average service times for the 11 beats in the First Precinct varied from a low of 24.95 to a high of 32.90 minutes. To avoid the estimating difficulties introduced by the different beat service times, total service time for each reporting area was input instead of total number of calls.

The empirical results and corresponding hypercube estimates based on the baseline input data are shown in tables 4-7 and 4-8. Comparison measures for these results and estimates are shown in Table 4-9. Examination of the results and comparison measures indicate reasonable agreement between the hypercube estimates and empirical results. Detailed inspection of the comparison also reveals the following:

- Workload - The hypercube estimates for utilization, average workload, and beat workloads are in almost perfect agreement with the corresponding empirical values. This is not surprising, however, since the same procedures are used to calculate both the empirical and hypercube values based on the same input data. Utilization and average workload are simple functions of the call rate, the average service time per call, and the number of units. Beat workloads are obtained by summing the workoads for the reporting areas in each beat. Comparison of the hypercube and empirical unit workloads indicates an average error of 9.53 percent. The rank sum of 16 is significant at the 1 percent level. Examination of the individual unit workloads indicates that the largest errors occur for units 1109 and 1110. In fact, the hypercube and empirical results for these units appear to be reversed. Detailed examinination of the input data, and discussions with department personnel failed to identify any reasons for these errors.

- Cross-beat dispatching - At the region, beat, and unit levels, the errors between the hypercube cross-beat estimates and the empirical results are large: 17.39 percent at the region level, 25.07 percent at the unit level, and 22.11 percent at the beat level. The rank sum for the unit cross-beat estimates is significant at the 5 percent level suggesting that the model is able to predict the relative rankings of the units despite large errors in the absolute estimates. Two factors which may have seriously affected the

Table 4-7

BASELINE EMPIRICAL DATA FOR ST. LOUIS COUNTY, FIRST PRECINCT, DAY WATCH, 1975[a]

Regional Data

Number of reporting areas	114
Number of units	11
Beat configuration	See Figure 4-1
Call rate (calls/hour)	11.56
Service time (minutes/call)	24.62
Average utilization	0.431
Region-wide average workload	0.431
Probability of saturation	b
Stan. dev. of unit workloads	0.0591
Max. workload imbalance	0.196
Region-wide travel time (min./call)	7.27
Fraction of cross-beat dispatches	0.3709

Unit Data

Unit	Workload	%	Cross-beat	%	Travel Time
1101	0.445	103.2	0.2677	72.2	6.96
1102	0.404	93.7	0.4603	124.1	6.42
1103	0.558	129.4	0.4120	111.1	6.66
1104	0.456	105.7	0.3775	101.8	7.71
1105	0.446	103.4	0.4573	123.3	6.63
1106	0.389	90.2	0.2143	57.8	7.93
1107	0.362	83.9	0.3911	105.5	9.10
1108	0.406	94.1	0.2819	76.0	9.20
1109	0.505	117.2	0.4494	121.2	7.11
1110	0.399	92.5	0.3250	87.6	5.95
1111	0.373	86.3	0.4000	107.9	7.92

Beat Data

Beat	Workload	%	Cross-beat	%	Travel Time
101	0.548	127.1	0.4177	112.7	7.70
102	0.345	80.0	0.2917	78.7	7.30
103	0.490	113.7	0.4120	111.1	6.33
104	0.477	110.7	0.4009	108.1	7.92
105	0.395	91.6	0.3415	92.1	6.15
106	0.425	98.6	0.3210	86.6	7.46
107	0.366	84.9	0.2483	67.0	9.14
108	0.456	105.8	0.4121	111.1	8.89
109	0.414	96.0	0.3758	101.3	6.90
110	0.474	110.0	0.3769	101.6	5.20
111	0.353	81.9	0.4043	109.0	8.57

[a]Based on 81 tours for the hours 8:00 a.m. to 2:00 p.m.

[b]Not determined from the emprical data.

Table 4-8

HYPERCUBE ESTIMATES FOR THE ST. LOUIS COUNTY BASELINE ASSESSMENT DATE, FIRST PRECINCT, DAY WATCH, 1975[a]

Regional Data

Number of reporting areas	114
Number of units	11
Beat configuration	See Figure 4-1
Dispatching policy	Beat unit first, infinite capacity queue, MCM
Preventive patrol policy	Proportional to reporting area workload
Call rate (calls/hour)	11.56
Service time (minutes/call)	24.62
Average utilization	0.431
Region-wide average workload	0.431
Probability of saturation	0.0105
Stan. dev. of unit workloads	0.059
Max. workload imbalance	0.195
Region-wide travel time (minutes/call)[b]	7.27
Fraction of cross-beat dispatches	0.4354

Unit Data

Unit	Workload	%	Cross-Beat	%	Travel Time[b]
1101	0.460	106.7	0.3557	81.7	7.01
1102	0.416	96.4	0.5152	118.3	6.40
1103	0.518	120.2	0.5464	125.5	6.62
1104	0.477	110.7	0.4758	109.3	8.03
1105	0.469	108.7	0.5517	126.7	8.26
1106	0.350	81.3	0.2118	48.7	7.92
1107	0.402	93.3	0.4554	104.6	9.30
1108	0.429	99.6	0.3937	90.4	7.51
1109	0.408	94.5	0.3969	91.2	6.85
1110	0.491	113.7	0.5071	116.5	5.64
1111	0.323	74.9	0.2569	59.0	6.59

Beat Data

Unit	Workload	%	Cross-Beat	%	Travel Time[b]
101	0.549	127.3	0.4596	105.6	7.13
102	0.345	79.9	0.4153	95.4	6.78
103	0.488	113.1	0.5176	118.9	5.58
104	0.478	110.8	0.4763	109.4	7.58
105	0.395	91.5	0.4681	107.5	6.46
106	0.425	98.6	0.3501	80.4	10.42
107	0.367	85.0	0.4018	92.3	9.01
108	0.456	105.7	0.4287	98.5	7.71
109	0.414	96.1	0.4073	93.6	6.55
110	0.474	110.0	0.4900	112.5	5.50
111	0.353	81.9	0.3225	74.1	7.76

[a] Based on data from 81 tours for the hours 8:00 a.m. to 2:00 p.m.

[b] Based on a travel speed calibrated to yield a region-wide travel time of 7.27 minutes.

Table 4-9

COMPARISON STATISTICS FOR THE BASELINE HYPERCUBE AND EMPIRICAL ESTIMATES[a] FOR ST. LOUIS COUNTY

Region Level	Empirical	Hypercube	Difference	Percent Difference
Avg. Workload	0.431	0.431	0.00	0.00
Probability of Saturation	b	0.0105	-	-
Cross-beat Dispatches	0.3709	0.4354	-0.0645	-17.39

Unit Level	Avg. Abs. Difference	Avg. Abs. % Difference	Abs. Rank Difference Sum
Workload	0.041	9.53	16 (sig., 1%)
Cross-beat Dispatches	0.093	25.07	22 (sig., 5%)
Travel Time-min. (sec.)	0.442(26.52)	6.08	22 (sig., 5%)
Beat Level			
Cross-beat Dispatches	0.082	22.11	34 (not sig.)
Travel Time-min. (sec.)	0.747(44.82)	10.28	12 (sig., 1%)

[a]See Tables 4-7 and 4-8.

[b]No empirical values for the probability of saturation were determined from the St. Louis data.

empirical results used for these comparisons are: (1) the unavailability of cross-beat data for administrative calls, and (2) the impact of calls in which more than one unit is assigned.* ~~In addition, even if the location of each administrative call is~~ known, the unit assignment rules used in the hypercube model may not be applicable since many administrative activities are unit rather than location dependent.

- Travel time - The unit and beat travel time estimates produced by the hypercube model agree reasonably well with the empirical results. Although the model estimates travel times more accurately for individual units than beats, the relative beat rankings predicted by the model are better than those based on the estimated unit travel times. The average errors for both the unit and beat levels are fairly small: 0.442 minutes (26.5 seconds) for unit times and 0.747 minutes (44.8 seconds) for beat times. Both sum rankings are statistically significant.

In addition to the baseline comparisons discussed above, additional hypercube estimates and empirical results were obtained for the St. Louis data to examine the effects of (1) the geographic placement of administrative calls, (2) the type of unit selection rule used to model dispatcher behavior, (3) data sample size on the accuracy of input data and hypercube estimates, and (4) call rate variations on hypercube estimates. Each of these issues is discussed below.

- Geographic placement of administrative calls - As noted above, the St. Louis County data documented the amount of unit time spent on administrative duties, but did not identify where the work was performed. Three options were considered for placement of the administrative calls: (1) distribution of the calls over all of the reporting areas in the precinct in the same proportion as dispatched and self-initiated calls, (2) distribution of the administative calls for each unit in an artificial reporting area in the geographic center of each unit's beat, and (3) distribution of the administrative calls for each unit over the reporting areas in his beat in the same proportion as the dispatched and self-initiated calls in the beat. The last option is used in the comparisons discussed above. The results of using each option in the hypercube model and comparing the estimates with the empirical results are shown in Table 4-10. These comparisons indicate that the baseline and precinct-wide option produce small improvements in travel time estimates at the beat level, and in cross-beat dispatching estimates

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*As noted earlier, every unit dispatched, whether as a primary or backup unit, was considered a separate incident in computing the empirical results and in preparing the input data for the hypercube model.

Table 4-10

COMPARISON STATISTICS FOR THREE GEOGRAPHIC PLACEMENTS OF ADMINISTRATIVE CALLS, ST. LOUIS COUNTY

Region Level

	Empirical	Hypercube	Difference	Percent Difference
Avg. Workload				
1. Baseline[a]	0.431	0.431	0.00	0.00
2. Precinct-Wide[b]	0.431	0.431	0.00	0.00
3. Artificial[c]	0.431	0.431	0.00	0.00
Cross-Beat Dispatches				
1. Baseline	0.3709	0.4354	-0.0645	-17.39
2. Precinct-Wide	0.3709	0.4416	-0.0707	-19.06
3. Artificial	0.3709	0.4367	-0.0658	-17.74

Unit Level

	Avg. Abs. Difference	Avg. Abs. % Difference	Abs. Rank Difference Sum
Workload			
1. Baseline	0.041	9.53	16 (sig., 1%)
2. Precinct-Wide	0.049	11.37	20 (sig., 1%)
3. Artificial	0.046	10.67	22 (sig., 5%)
Cross-Beat Dispatches			
1. Baseline	0.093	25.07	22 (sig., 5%)
2. Precinct-Wide	0.088	23.73	20 (sig., 1%)
3. Artificial	0.104	28.04	30 (not sig.)
Travel Time-min. (sec.)			
1. Baseline	0.442(26.52)	6.08	22 (sig., 5%)
2. Precinct-Wide	0.545(32.70)	7.50	20 (sig., 1%)
3. Artificial	0.809(48.54)	11.13	30 (not sig.)

Beat Level

	Avg. Abs. Difference	Avg. Abs. % Difference	Abs. Rank Difference Sum
Cross-Beat Dispatches			
1. Baseline	0.082	22.11	34 (not sig.)
2. Precinct-Wide	0.086	23.19	30 (not sig.)
3. Artificial	0.083	22.38	28 (not sig.)
Travel Time-min. (sec.)			
1. Baseline	0.747(44.82)	10.28	12 (sig., 1%)
2. Precinct-Wide	0.679(40.74)	9.34	12 (sig., 1%)
3. Artificial	0.734(44.04	10.10	20 (sig., 1%)

[a]Baseline: administrative calls for each unit are distributed entirely within that unit's beat in the same distribution as dispatched and self-initiated calls.

[b]Precinct-Wide: administrative calls are distributed throughout the precinct in the same proportion as dispatched and self-initiated calls.

[c]Artificial: administrative calls for each unit are placed in an artificial reporting area located in the geographic center of each beat.

at the unit level. The artificial reporting area option produces larger estimating errors for cross-beat dispatching and travel times at the unit level.

- Unit selection rule - Hypercube runs were made for each of the fixed preference dispatching rules for unit selection available in the hypercube model. The comparison measures for each run are shown in Table 4-11. In general, the effects of the different unit selection rules are relatively minor. The MCM and EMCM rules produce better hypercube estimates supporting the use of the MCM rule for the baseline comparisons for St. Louis County. For all of the selection rules, the estimates for unit workloads, and for unit and beat travel times are consistently better than model estimates for the fraction of beat and unit cross-beat dispatches. All of the hypercube estimates, except cross-beat dispatches at the beat level, produce unit and beat rankings that are very close to the empirical results.

- Effect of data sampling on input data and hypercube accuracy - The baseline comparisons for St. Louis County are based on a 100 percent sample of radio dispatches for 81 six-hour tours. To examine the effects of sampling on the accuracy of the input data and hypercube estimates, three samples were drawn from the 5,632 radio calls. The samples consisted of approximately 50, 25, and 10 percent of the call population. The empirical results based on these samples are shown in Table 4-12. Not surprisingly, as sample size decreases, the accuracy of the empirical estimates also diminishes. The degree of error, however, is relative small for several of the input data items. Even the 10 percent sample (only 4.7 calls per reporting area) produces relatively good results:

Data Item	Population Value*	10 Percent Estimate	Percent Error
Service min./hr.	284.6	281.4	1.12%
Service time/call	24.62	25.58	-3.90
Call rate	11.56	11.00	4.84
Travel time	7.27	7.60	-4.54
Cross-beat dispatch fraction	0.3709	0.4279	-15.37

Except for cross-beat dispatching, all of the estimates based on the 10 percent sample are within 5 percent of population values. To investigate the effects of the data samples on the workload distribution over the reporting areas, hypercube estimates were determined using the corresponding workload distribution for each sample. To detect the effects of the altered workload distributions, all other input data were selected from the baseline empirical data base (see Table 4-7). The comparison statistics for these hypercube runs are shown in Table 4-13. The hypercube estimates show considerable stability for the 50 and 25 percent sample and only slight degradation for the 10 percent sample. These results suggest that hypercube results obtained with workload distributions based on samples that represent only 25 percent of the total data may not

*Derived from 100 percent sample.

Table 4-11

COMPARISON STATISTICS FOR FOUR DISPATCHER UNIT SELECTION RULES
ST. LOUIS COUNTY

Region Level

	Empirical	Hypercube	Difference	Percent Difference
Avg. Workload				
1. Baseline-MCM	0.431	0.431	0.00	0.00
2. EMCM	0.431	0.431	0.00	0.00
3. SCM	0.431	0.431	0.00	0.00
4. ESCM	0.431	0.431	0.00	0.00
Cross-beat Dispatches				
1. Baseline-MCM	0.3709	0.4354	-0.0645	-17.39
2. EMCM	0.3709	0.4355	-0.0646	-17.42
3. SCM	0.3709	0.4353	-0.0644	-17.36
4. ESCM	0.3709	0.4365	-0.0656	-17.69

Unit Level

Workload	Avg. Abs. Difference	Avg. Abs. % Difference	Abs. Rank Difference Sum
1. Baseline-MCM	0.041	9.53	16 (sig., 1%)
2. EMCM	0.038	8.82	18 (sig., 1%)
3. SCM	0.049	11.37	22 (sig., 5%)
4. ESCM	0.049	11.37	20 (sig., 1%)
Cross-beat Dispatches			
1. Baseline-MCM	0.093	25.07	22 (sig., 5%)
2. EMCM	0.091	24.53	24 (sig., 5%)
3. SCM	0.100	26.96	26 (sig., 10%)
4. ESCM	0.121	32.62	28 (sig., 10%)
Travel Time-min.(sec.)			
1. Baseline-MCM	0.442(26.52)	6.08	22 (sig., 5%)
2. EMCM	0.398(23.88)	5.47	22 (sig., 5%)
3. SCM	0.609(36.54)	8.38	22 (sig., 5%)
4. ESCM	0.637(38.22)	8.76	28 (sig., 10%)

Beat

Cross-beat Dispatches			
1. Baseline-MCM	0.082	22.11	34 (not sig.)
2. EMCM	0.082	22.11	34 (not sig.)
3. SCM	0.080	21.57	34 (not sig.)
4. ESCM	0.087	23.46	32 (not sig.)
Travel Time-min. (sec.)			
1. Baseline-MCM	0.747(44.82)	10.28	12 (sig., 1%)
2. EMCM	0.660(39.60)	9.08	12 (sig., 1%)
3. SCM	0.734(44.04)	10.10	18 (sig., 1%)
4. ESCM	0.732(43.92)	10.07	16 (sig., 1%)

Table 4-12

EMPIRICAL STATISTICS BASED ON 100, 50, 25, AND 10 PERCENT SAMPLES OF THE ST. LOUIS COUNTY BASELINE DATA

	Empirical Data Base			
Sample size (%)	100.0	50.0	25.0	10.0
No. of Calls	5,362	2,681	1,341	536
Calls/Beat (11)	487.5	243.7	121.9	48.7
Calls/Reporting Area (114)	47.0	23.5	11.8	4.7
• Number of Incidents				
Dispatched & Self-Initiated	2,836	2,830	2,708	2,817
Administrative	2,526	2,532	2,654	2,545
Total	5,362	5,362	5,362	5,362
• Number of Service-Minutes/Hour				
Dispatched & Self-Initiated	164.1	163.9	158.8	153.3
Administrative	120.5	120.5	136.2	128.1
Total	284.6	284.4	295.0	281.4
• Service Time/Call				
Dispatched & Self-Initiated	26.95	27.17	27.39	26.62
Administrative	22.00	21.22	22.60	24.43
Total (weighted)	24.62	24.37	25.03	25.58
• Call Rate[a]				
Dispatched & Self-Initiated	6.09	6.03	5.80	5.76
Administrative	5.48	5.68	6.03	5.24
Total (weighted)	11.56	11.67	11.79	11.00
• Travel Time (minutes/call)				
Dispatched & Self-Initiated	7.27	7.22	7.59	7.60
Administrative	b	b	b	b
~~Total (weighted)~~	7.27	7.22	7.59	7.60
• Cross-beat Dispatching Fraction (regionwide)				
Dispatched & Self-Initiated	0.3709	0.3560	0.3984	0.4279
Administrative	b	b	b	b
Total (weighted)	0.3709	0.3560	0.3984	0.4279

[a]Call rate equals the number of service minutes per hour divided by the average service time per call.

[b]Assignment locations and arrival times were not available for administrative calls.

Table 4-13

COMPARISON STATISTICS FOR FOUR WORKLOAD DISTRIBUTIONS BASED ON SAMPLES OF 100, 50 25, AND 10 PERCENT OF THE ST. LOUIS COUNTY BASELINE DATA[a]

Region Level	Empirical	Hypercube	Difference	Percent Difference
Avg. Workload				
1. 100%[b]	0.431	0.431	0.00	0.00
2. 50	0.431	0.431	0.00	0.00
3. 25	0.431	0.431	0.00	0.00
4. 10	0.431	0.431	0.00	0.00
Cross-beat Dispatches				
1. 100%	0.3709	0.4359	-0.0650	-17.52
2. 50	0.3709	0.4389	-0.0680	-18.33
3. 25	0.3709	0.4410	-0.0701	-18.90
4. 10	0.3709	0.4474	-0.0765	-20.63

Unit Level	Average Abs. Difference	Average Abs. % Difference	Abs. Rank Difference Sum
Workload			
1. 100%	0.041	9.53	21(sig., 5%)
2. 50	0.045	10.44	22(sig., 5%)
3. 25	0.043	9.97	16(sig., 1%)
4. 10	0.052	12.06	28(sig., 10%)
Cross-beat Dispatches			
1. 100%	0.096	25.88	26(sig., 10%)
2. 50	0.088	23.73	24(sig., 5%)
3. 25	0.097	26.15	30(not sig.)
4. 10	0.084	22.65	20(sig., 1%)
Travel Time-min.(sec.)			
1. 100%	0.460(27.6)	6.33	22(sig., 5%)
2. 50	0.485(29.1)	6.67	18(sig., 1%)
3. 25	0.395(23.7)	5.43	16(sig., 1%)
4. 10	0.694(41.6)	9.95	24(sig., 5%)
Beat Level			
Cross-beat Dispatches			
1. 100%	0.081	21.84	34(not sig.)
2. 50	0.083	22.38	30(not sig.)
3. 25	0.083	22.38	28(not sig.)
4. 10	0.099	26.69	38(not sig.)
Travel Time-min. (sec.)			
1. 100%	0.675(40.5)	9.28	16(sig., 1%)
2. 50	0.703(42.2)	9.67	14(sig., 1%)
3. 25	0.730(43.8)	10.04	16(sig., 1%)
4. 10	0.725(43.5)	9.97	14(sig., 1%)

[a]The input data used for each hypercube run was identical to the baseline data set except for the geographic distribution of workload.

[b]All four workload distributions were based on unweighted incident counts for each reporting area. As a result, the comparison statistics for the 100 percent sample presented in this table can be compared with the results shown in Table 4-9 to determine the effects of using total service time versus incident counts for workload distributions.

vary significantly from estimates based on 100 percent samples.

- Call rate variations - To test the effects of inaccuracies in the input call rate, several hypercube runs were made with call rates ranging from 9.13 to 11.56 calls per hour (the baseline value). All other input data items corresponded to the baseline empirical data set. This range of call rates was selected in order to minimize the percent error between the hypercube and empirical results for the fraction of cross-beat dispatching at the region level. The results of these runs are shown in Table 4-14. As the input call rate decreases, the hypercube estimate for regionwide cross-beat dispatching fraction also decreases, bringing it closer to the empirical value. Although the size of the errors for cross-beat dispatching also decrease at the beat and unit levels, the sum of the rank differences remain nearly constant for both. Unit workload and travel time estimates both decline in accuracy as the call rate is decreased. Interestingly, travel times at the beat level remain almost constant for all four call rates.

Pasadena. The second souce of empirical data for the assessment activities was Pasadena, California. This city differs in many ways from St. Louis County. Although Pasadena encompasses an area of only 21 square miles--less than one-fifth the size of the First Precinct in St. Louis County--the populations of both areas are approximately the same (i.e., slightly more than 100,000). The higher population density for Pasadena reflects its more urbanized development in contrast to the predominately low-density suburban environment of the First Precinct in St. Louis County. The Pasadena Police Department uses a geographic reporting system based on 134 reporting areas. The average reporting area in Pasadena covers 0.16 square miles compared to an average area of 1.05 square miles in St. Louis County.

Also in contrast to the St. Louis County Police Department, the Pasadena Police Department maintains no standardized radio tape which could be used to collect data for the hypercube assessment. The only source for much of the required data was the card filled out by dispatchers at the time of each radio assignment. Approximately 60,000 dispatch records are produced each year. To obtain the data

Table 4-14

COMPARISON STATISTICS FOR FOUR CALL RATES WITH THE ST. LOUIS COUNTY BASELINE DATA

Region Level

Avg. Workload	Empirical	Hypercube	Difference	Percent Difference
1. Baseline-11.56 calls/hr.	0.431	0.431	0.000	0.00
2. 10.75	0.431	0.401	0.030	6.96
3. 9.94	0.431	0.371	0.060	13.92
4. 9.13	0.431	0.341	0.090	20.88

Cross-beat Dispatches	Empirical	Hypercube	Difference	Percent Difference
1. 11.56 calls/hr.	0.3709	0.4354	-0.0645	-17.39
2. 10.75	0.3709	0.4054	-0.0345	-9.30
3. 9.94	0.3709	0.3752	-0.0043	-1.16
4. 9.13	0.3709	0.3449	0.0260	7.01

Unit Level

Workload	Average Abs. Difference	Average Abs. % Difference	Abs. Rank Difference Sum
1. 11.56 calls/hr.	0.041	9.53	16 (sig., 1%)
2. 10.75	0.043	9.97	17 (sig., 1%)
3. 9.94	0.065	15.08	20 (sig., 1%)
4. 9.13	0.091	21.11	20 (sig., 1%)

Cross-beat Dispatches	Average Abs. Difference	Average Abs. % Difference	Abs. Rank Difference Sum
1. 11.56 calls/hr.	0.093	25.07	22 (sig., 5%)
2. 10.75	0.081	21.84	24 (sig., 5%)
3. 9.94	0.073	19.68	24 (sig., 5%)
4. 9.13	0.063	16.99	24 (sig., 5%)

Travel Time-min. (sec.)	Average Abs. Difference	Average Abs. % Difference	Abs. Rank Difference Sum
1. 11.56 calls/hr.	0.442(26.5)	6.08	22 (sig., 5%)
2. 10.75	0.601(36.1)	8.27	22 (sig., 5%)
3. 9.94	0.667(40.0)	9.17	24 (sig., 5%)
4. 9.13	0.736(44.2)	10.12	28 (sig., 10%)

Beat Level

Cross-beat Dispatches	Average Abs. Difference	Average Abs. % Difference	Abs. Rank Difference Sum
1. 11.56 calls/hr.	0.082	22.11	34 (not sig.)
2. 10.75	0.059	15.91	34 (not sig.)
3. 9.94	0.051	13.75	34 (not sig.)
4. 9.13	0.049	13.21	34 (not sig.)

Travel Time-min. (sec.)	Average Abs. Difference	Average Abs. % Difference	Abs. Rank Difference Sum
1. 11.56 calls/hr.	0.747(44.8	10.28	12 (sig., 1%)
2. 10.75	0.743(44.6)	10.22	12 (sig., 1%)
3. 9.94	0.735(44.1)	10.11	16 (sig., 1%)
4. 9.13	0.735(44.1)	10.11	16 (sig., 1%)

needed for the assessment, all dispatch records were examined for two periods in 1976 covering a total of 38 days. A total of 6,892 records were obtained consisting of 6,190 dispatched and 702 self-initiated incidents. Administrative workload is not recorded on dispatch records.

To obtain a consistent data base for the assessment, the following requirements were used to screen the Pasadena data:

- Field patrol unit workload - The Pasadena dispatch data included assignments given to special units whose prime responsibility is report writing, and incidents reported to the police by citizens at police headquarters. These dispatch cards were eliminated since they represented work that was not handled by field patrol units.

- Time of day - The dispatch data were divided into three watches reflecting the night, day, and afternoon tours which varied considerably in workload intensity.

- Middle six hours of each watch - The Pasadena Police Department uses three 10-hour watches per day. To eliminate the effects of the six hours of overlap between watches and watch changeovers, only the middle six hours of each watch were used to obtain empirical statistics. The three subtours used were (1) the night watch, 1:30 a.m. to 7:30 a.m.; (2) the day watch, 9:30 a.m. to 3:30 p.m.; and (3) the afternoon watch, 5:30 p.m. to 11:30 p.m.

The effects of these requirements on the size of the final data base are summarized below:

Requirement	No. of Records
Original 38 days	6,892
Field units only	6,253
Middle six hours	4,611
1:30 a.m. - 7:30 a.m.	787
9:30 a.m. - 3.30 p.m.	1,521
5:30 p.m. - 11:30 p.m.	2,303

Of the 4,611 field unit incidents, 4,001 were handled by beat units and 610 were handled by supervisors, uniform agents, meter maids, and other field units.

The daily assignment sheets for the department were used to determine the number of units and beat configuration for each watch over the 38 days of interest. The results are summarized in Table 4-15. Over the 114 watch-days, the number of units fielded varies from 6 to 15. Even more variation exists in the number of different configurations used within each watch. Over the 38 days examined, 15 configurations were used on the night watch, 22 configurations were used on the day watch, and 21 configurations were used on the afternoon watch. The most frequently used configurations appear on the night watch where one configuration for eight units, and another for nine units were each used on nine of the 38 days examined. Despite the small incident count for the night watch, these two configurations were used to obtain the baseline empirical data.

With the dispatch records discussed above, plus additional information obtained from the department's Planning and Research Office, empirical results and input data for the hypercube model were produced. These results are summarized below.

- Geographic data - Regardless of the number of units fielded, the Pasadena Police Department always uses the same seven geographic beats (see Figure 4-2). Units are assigned to two or more beats, or doubled up in single beats as needed. The geographic coordinates and area for each reporting area were supplied by the Planning and Research Office. The number of reporting areas in each beat and resulting beat sizes are given below:

Beat	Number of Reporting Areas	Size (square miles)
1	22	6.57
2	18	2.23
3	18	2.73
4	18	3.54
5	20	1.54
6	14	1.57
7	24	2.79
Total	134	20.97

Table 4-15

NUMBER OF BEAT UNITS FIELDED AND BEAT CONFIGURATIONS USED DURING THE 38 DAYS COVERED BY THE PASADENA EMPIRICAL DATA

	Watch			
No. of Units	I Night	II Day	III Afternoon	Total
6	5*	0	0	5
7	7	2	0	9
8	11	5	0	16
9	13	7	3	23
10	2	6	4	12
11	0	7	12	19
12	0	5	12	17
13	0	6	5	11
14	0	0	1	1
15	0	0	1	1
	38	38	38	114
No. of Different Beat Configurations	15	22	21	58

*Entry indicates that on five occasions there were exactly six units fielded on the night watch.

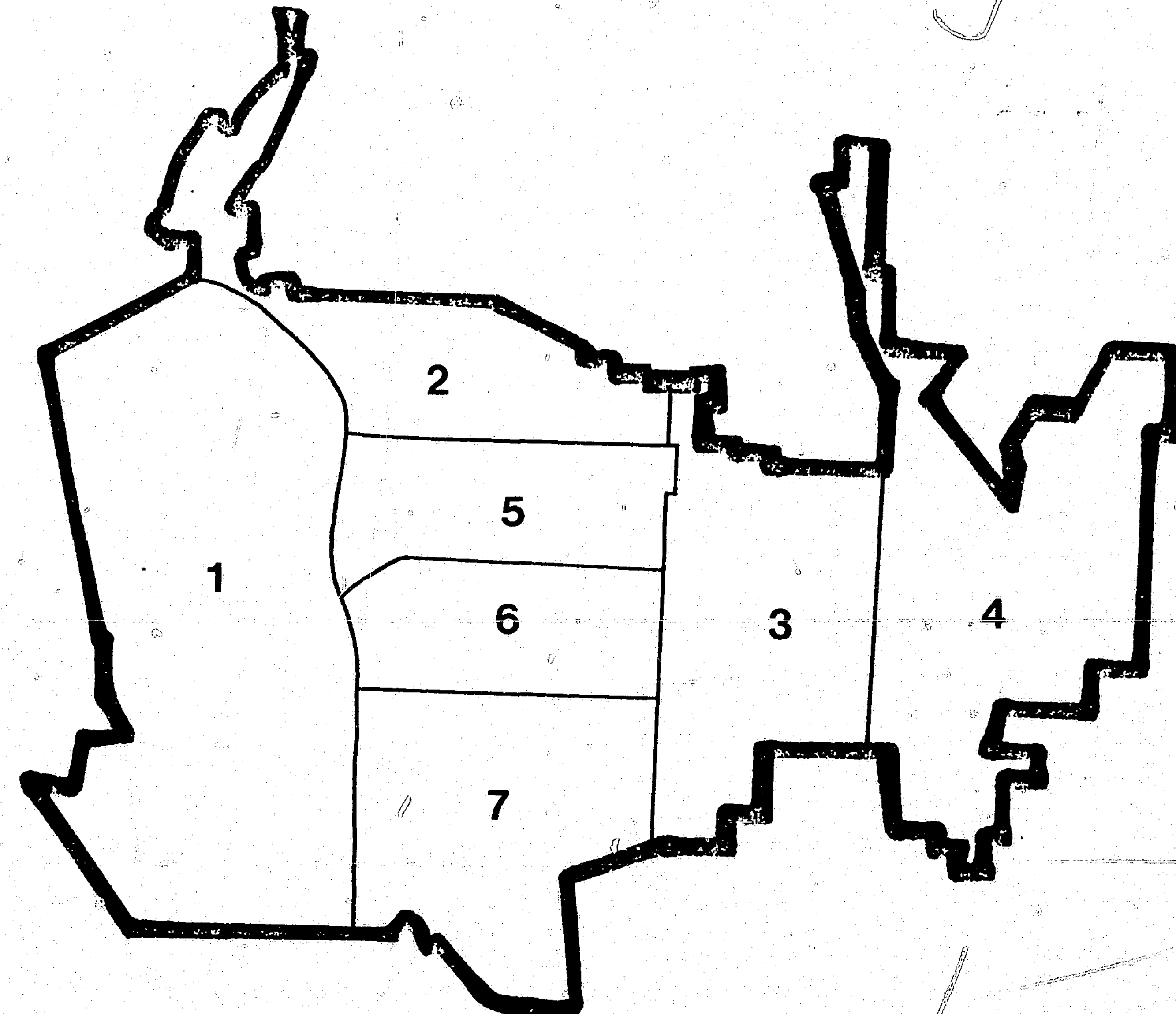

Figure 4-2

SEVEN-BEAT CONFIGURATION, PASADENA, CALIFORNIA, 1976

• Administrative workload - Estimates of the amount of administrative workload for each patrol unit were supplied by the Planning and Research office. A summary of these estimates for each watch is presented in Table 4-16. These estimates include lunch-breaks, court appearances, roll-call, end-of-watch activities, and routine patrol actions such as traffic citations, traffic hazards, car and pedestrian checks, follow-up investigations, and report writing. It is important to note that the definition used for administrative work in Pasadena differs slightly from that used for St. Louis County; in Pasadena, administrative workload included some activities which were defined as dispatched assignments in the St. Louis County data. As a result, total administrative workload in Pasadena represented a greater fraction of total unit workload than was found in St. Louis County.

• Call rate - The call rates for the two baseline configurations for the night watch were determined by dividing the average number of service minutes per hour for all field units by the average service time per call (see Table 4-17). The service minutes for CFS incidents were adjusted to reflect incidents with multiple unit assignments. For both configurations, the non-CFS workload represented over two-thirds of all unit workload.

• Service time - The definition used to determine service times in Pasadena was identical to that used for St. Louis County (i.e., the difference between time dispatched and time cleared). Based on approximately two-thirds of the available records, service times of 22.3 minutes and 21.8 minutes were calculated for the eight- and nine-unit configurations.

• Travel speed - Like St. Louis County, Pasadena had no reliable data on average travel speed. Accordingly, an estimate of regionwide travel time based on empirical data was used to obtain a calibrated travel speed. Data based on the eight-unit configuration produced a travel time of 4.65 minutes which yielded a calibrated travel speed of 19.1 miles per hour. The overall travel time of 3.65 minutes for the nine-unit configuration produced a calibrated travel speed of 24.3 miles per hour.

• Dispatch policy - Based on discussions with department personnel, the following dispatching rules were adopted: (1) beat car first, (2) zero capacity queue, and (3) an EMCM unit assignment rule. Although the beat car first rule is the stated department policy for unit selection, personnel at the department noted that some stacking of calls at the beat level was not unusual during busy times of the day. No efforts were made to ascertain the extent to which this occurred. The zero capacity queue was adopted to reflect the fact that when all beat units are busy, dispatchers in Pasadena routinely assign incidents to non-beat units (e.g., supervisory units, detectives, and in some instances, meter maids).

• Preventive patrol policy - The Pasadena Police Department allows each beat unit to determine its own patrol pattern within its beat, and maintains no records which document actual patterns used. Personnel in the Department suggested that as a general rule,

Table 4-16

ESTIMATED NON-CFS WORKLOAD FOR FIELD PATROL UNITS, PASADENA ASSESSMENT DATA

Time	Total Minutes/ Unit	Minutes/Unit/ Hour
Night Watch		
23:30-1:30	81.4	40.7
1:30-7:30	147.8	24.6*
7:30-9:30	55.7	27.9
TOTAL	284.9	28.4
Day Watch		
7:30- 9:30	91.5	45.8
9:30-15:30	203.3	33.9
15:30-17:30	70.2	35.1
TOTAL	365.0	36.5
Afternoon Watch		
15:30-17:30	89.7	44.9
17:30-23:30	193.3	32.2
23:30- 1:30	67.0	33.5
TOTAL	350.0	35.5

*Used for the baseline data for Pasadena.

Table 4-17

EMPIRICAL PATROL DATA FOR PASADENA
NIGHT WATCH, 1976

	Configuration	
	Eight-Unit	Nine-Unit
• Number of Incidents	165	157
• Number of CFS Service-Minutes/Hour[a]	96.6 (N=136)	85.8 (N=136)
• Number of Non-CFS Service-Minutes/Hour[b]	196.8	221.4
• Total Service-Minutes/Hour	293.4	307.2
• Service Time/Call (minutes)	22.3 (N=113)	21.8 (N=92)
• Call Rate[c]	13.2	
• Travel Time/Call (minutes)	4.65 (N=97)	3.65 (N=73)

[a]Adjusted for multiple car assignments

[b]Based on a fixed administrative time/unit for 1:30 a.m. to 7:30 a.m. (See Table 4-16).

[c]Total service-minutes/hour divided by service-time/call.

beat units tend to patrol higher workload areas more frequently. Consequently, the preventive patrol factors for the hypercube runs were set according to the workload distribution by reporting area.

- Geographic workload distribution - Description of the geographic distribution of field workload was hampered by (1) small data samples for each configuration, (2) a lack of department records documenting the location of administrative workload, and (3) service times which varied considerably from beat to beat (i.e., from 18.6 to 32.8 minutes). The alternative procedures for distributing administrative workload that were considered in St. Louis County were also considered in Pasadena. Placement of each units's administrative workload in an artificial reporting area located in the center of his beat produced the best assessment comparisons and was used as the baseline option. The variable service time problem was corrected by using total service minutes for each reporting area instead of incident counts. The low sample size for each configuration was partially overcome by combining the empirical results for each configuration into a composite profile for comparison with a similar profile based on the hypercube results for each configuration.

The empirical results and corresponding hypercube estimates for both the eight- and nine-unit configurations are shown in tables 4-18 through 4-21. Comparison measures for each configuration and composite results are shown in Table 4-22.

The following observations are based on the comparison statistics in Table 4-22.

- Workload - The regionwide average workload estimates produced by the hypercube model are reasonably close to the empirical results despite the small data base for each comparison. It is believed that the errors between the empirical and hypercube results are due primarily to the fact that department dispatchers do not always call non-beat units when every beat unit is busy. As a result, the zero capacity queue option used in this hypercube analysis only approximates actual dispatcher behavior. Hypercube estimates for unit workloads are as accurate as those derived with the St. Louis County data, The agreement between hypercube and empirical unit workloads is not surprising in view of the relative volume of administrative work that was added to each unit's workload. The administrative workloads, ~~which were~~ based on Department estimates, are not considered as reliable as the dispatch records that were used to obtain CFS workload. The hypercube estimate for the probability of saturation for the composite result appears to be reasonably accurate despite the large errors for the individual configurations.

- Cross-beat dispatching - At every level of comparison, the hypercube model produces very poor estimates of cross-beat dispatching.

Table 4-18

BASELINE EMPIRICAL DATA FOR PASADENA,
EIGHT-UNIT CONFIGURATION,
NIGHT WATCH, NINE TOURS

Region Data

Number of reporting areas	134
Number of units	8
Beat configuration	1112111*
Call rate (calls/hour)	13.16
Service time (minutes/call)	22.3
Average utilization	0.611
Region-wide average workload	0.585
Probability of saturation	0.0433
Stan. dev. of unit workloads	0.0897
Max. workload imbalance	0.276
Region-wide travel time (min./call)	4.65
Fraction of cross-beat dispatches	0.5200

Unit Data

Unit	Workload	%	Cross-beat	%	Travel Time
1	0.503	86.0	0.6667	128.2	4.22
2	0.534	91.3	0.5556	106.8	8.56
3	0.577	98.6	0.6667	128.2	3.00
41	0.514	87.9	0.4286	82.4	3.86
42	0.514	87.9	0.4286	82.4	3.86
5	0.779	133.2	0.5172	99.5	4.59
6	0.670	114.5	0.4000	76.9	3.88
7	0.586	100.1	0.5333	102.6	4.88

Beat Data

Beat	Workload	%	Cross-beat	%	Travel Time
1	0.579	94.8	0.7273	139.9	7.45
2	0.623	102.0	0.7500	144.2	6.00
3	0.497	81.3	0.5714	109.9	3.43
41	1.008	165.0	0.2000	38.5	4.20
42	1.008	165.0	0.2000	38.5	4.20
5	0.735	120.3	0.3636	69.9	5.05
6	0.756	123.7	0.5714	109.9	2.90
7	0.692	113.3	0.4615	88.8	4.00

*Configuration 1112111 indicates the number of units assigned to each of the seven beats (i.e., one unit to Beats 1,2,3,5,6, and 7, and two units to Beat 4).

Table 4-19

BASELINE EMPIRICAL DATA FOR PASADENA, NINE-UNIT CONFIGURATION, NIGHT WATCH, NINE TOURS

Region Data

Number of reporting areas	134
Number of units	9
Beat configuration	1112121
Call rate (calls/hour)	14.07
Service time (minutes/call)	21.83
Average utilization	0.569
Region-wide average workload	0.519
Probability of saturation	0.0857
Stan. dev. of unit workloads	0.0500
Max. workload imbalance	0.163
Region-wide travel time (min./call)	3.65
Fraction of cross-beat dispatches	0.5205

Unit Data

Unit	Workload	%	Cross-beat	%	Travel Time
1	0.434	83.6	0.3333	64.0	3.33
2	0.597	115.0	0.5455	104.8	4.08
3	0.559	107.7	0.5385	103.4	3.62
41	0.470	90.6	0.3333	64.0	2.00
42	0.470	90.6	0.3333	64.0	2.00
5	0.537	103.5	0.3333	64.0	4.07
61	0.518	99.8	0.8667	166.5	3.00
62	0.518	99.8	0.8667	166.5	3.00
7	0.569	109.6	0.4000	76.8	4.60

Beat Data

Beat	Workload	%	Cross-beat	%	Travel Time
1	.700	123.0	0.8182	157.2	4.09
2	.591	103.9	0.2857	54.9	4.14
3	.535	94.0	0.0000	0.0	2.33
41	.946	166.3	0.3333	64.0	3.83
42	.946	166.3	0.3333	64.0	3.83
5	.687	120.7	0.4444	85.4	3.39
61	.993	174.5	0.6000	115.3	8.20
62	.993	174.5	0.6000	115.3	8.20
7	.669	117.6	0.7000	134.5	2.65

Table 4-20

HYPERCUBE ESTIMATES FOR THE PASADENA EIGHT-UNIT BASELINE DATA, NIGHT WATCH, NINE TOURS

Region Data

Number of reporting areas	141[a]
Number of units	8
Beat configuration	1112111
Dispatching policies	Beat unit first, zero capacity queue, EMCM
Preventive patrol policy	Proportional to reporting area workload
Call rate (calls/hour)	13.16
Service time (minutes/call)	22.30
Average utilization	0.611
Region-wide average workload	0.572
Probability of saturation	0.0650
Stan. dev. of unit workloads	0.072
Max. workload imbalance	0.186
Region-wide travel time (minutes/call)	4.65[b]
Fraction of cross-beat dispatches	0.4354

Unit Data

Unit	Workload	%	Cross-beat	%	Travel Time
1	0.507	88.7	0.4295	85.0	6.40
2	0.578	101.1	0.5439	107.7	4.05
3	0.555	97.0	0.6079	120.4	4.78
41	0.498	87.1	0.2729	54.0	5.15
42	0.498	87.1	0.2729	54.4	5.17
5	0.661	115.6	0.6148	121.7	3.73
6	0.683	119.5	0.6469	128.1	3.99
7	0.594	103.9	0.5389	106.7	4.53

Beat Data

Beat	Workload	%	Cross-beat	%	Travel Time
1	0.588	96.2	0.4733	93.7	6.35
2	0.625	102.3	0.5488	108.6	4.53
3	0.488	79.8	0.5240	103.7	4.35
41	1.001	163.7	0.2296	45.4	4.69
42	1.001	163.7	0.2296	45.4	4.69
5	0.751	122.8	0.6368	126.1	4.03
6	0.763	124.8	0.6612	130.9	3.95
7	0.676	110.5	0.5662	112.1	4.90

[a]One hundred thirty-four reporting areas plus one artificial area for each of the seven geographic beats.

[b]Based on a travel speed calibrated to yield a region-wide travel time of 4.65 minutes.

Table 4-21

HYPERCUBE ESTIMATES FOR THE PASADENA NINE-UNIT BASELINE DATA, NIGHT WATCH, NINE TOURS

Region Data

Number of reporting areas	141[a]
Number of units	9
Beat configuration	1112121
Dispatch policies	Beat unit first, zero capacity queue, EMCM
Preventive patrol policy	Proportional to reporting area workload
Call rate (calls/hour)	14.07
Service time (minutes/call)	21.83
Average utilization	0.569
Region-wide average workload	0.545
Probability of saturation	0.0413
Stan. dev. of unit workloads	0.078
Max. workload imbalance	0.195
Region-wide travel time (minutes/call)	3.65[b]
Fraction of cross-beat dispatches	0.4446

Unit Data

Unit	Workload	%	Cross-beat	%	Travel Time
1	0.490	89.8	0.2759	62.0	5.15
2	0.537	98.5	0.4848	109.0	3.26
3	0.512	93.8	0.4990	112.2	3.72
41	0.453	83.0	0.2096	47.1	4.17
42	0.453	83.0	0.2110	47.4	4.17
5	0.623	114.3	0.5750	129.3	2.98
61	0.647	118.7	0.5726	128.8	3.22
62	0.647	118.7	0.5728	128.8	3.22
7	0.547	100.3	0.4423	99.5	3.53

Beat Data

Beat	Workload	%	Cross-beat	%	Travel Time
1	0.695	122.1	0.4680	105.3	5.18
2	0.598	105.2	0.5173	116.3	3.59
3	0.524	92.1	0.4910	110.4	3.48
41	0.930	163.5	0.2008	45.2	3.98
42	0.930	163.5	0.2008	45.2	3.98
5	0.705	124.0	0.6073	136.6	3.07
61	0.994	174.7	0.4181	94.0	2.74
62	0.994	174.7	0.4181	94.0	2.74
7	0.673	118.4	0.5277	118.7	3.74

[a]One hundred thirty-four reporting areas plus one artificial area for each of the seven geographic beats.

[b]Based on a travel speed calibrated to yield a region-wide travel time of 3.65 minutes.

Table 4-22

COMPARISON STATISTICS FOR THE
HYPERCUBE AND EMPIRICAL ESTIMATES BASED ON THE
PASADENA BASELINE DATA

Region Level	Empirical	Hypercube	Difference	Percent Difference
Avg. Workload				
Eight-unit	0.585	0.572	0.013	2.22
Nine-unit	0.519	0.545	-0.026	-5.01
Composite[a]	0.552	0.559	-0.007	-1.27
Probability of Saturation				
Eight-unit	0.0433	0.0650	-0.0217	-50.12
Nine-unit	0.0857	0.0413	0.0444	51.81
Composite	0.0645	0.0532	0.0113	17.52
Cross-beat Dispatches				
Eight-unit	0.5200	0.4354	0.0846	16.27
Nine-unit	0.5205	0.4446	0.0759	14.58
Composite	0.5203	0.4400	0.0803	15.43

Unit Level	Avg. Abs. Difference	Avg. Abs. % Difference	Abs. Rank Difference Sum
Workload			
Eight-unit	0.030	5.12	8 (sig., 5%)
Nine-unit	0.063	12.14	22 (not sig.)
Composite	0.0465	8.42	15 (not sig.)
Cross-beat Dispatches			
Eight-unit	0.121	23.27	20 (not sig.)
Nine-unit	0.142	27.28	17 (not sig.)
Composite	0.1315	25.28	18.5 (not sig.)
Travel Time-min. (sec.)			
Eight-unit	1.55(93.0)	33.33	30 (not sig.)
Nine-unit	1.08(64.8)	29.59	29 (not sig.)
Composite	1.315(78.9)	31.69	29.5 (not sig.)
Beat Level[c]			
Cross-beat Dispatches			
Eight-unit	0.143	27.50	17 (not sig.)
Nine-unit	0.246	47.26	18 (not sig.)
Composite	0.1945	37.39	17.5 (not sig.)
Travel Time-min. (sec.)			
Eight-unit	0.99(59.4)	23.86	10 (sig., 5%)
Nine-unit	1.40(84.0)	33.73	18 (not sig.)
Composite	1.195(71.7)	28.80	14 (not sig.)

[a]Composite values for all hypercube and empirical estimates on the region level, and for average absolute differences and absolute rank difference sums on the beat and unit levels are computed as the weighted average of the values for the eight- and nine-unit configurations.

[b]Significance test for the composite rank difference sum is based on the critical value for an eight-unit configuration.

[c]Beat data comparisons are calculated on the basis of seven geographic beats.

In most instances, the average absolute percent difference is quite high (up to 47 percent in one instance), and the rank difference sums indicate no agreement in the relative rankings of the individual beat or unit estimates.

- Travel time - At both the unit and beat level, the hypercube travel time estimates are significantly different from the empirical values. The average absolute differences between individual hypercube and empirical estimates usually exceed one minute.

In general, the baseline comparisons for Pasadena offer little support for the accuracy or usefulness of the hypercube model. It is important to note, however, that these results are based on very small data sets.* Further work is needed to identify more clearly what size data base is needed to obtain useful results, and what department characteristics should be used to determine how much data is needed. The answers to these questions may yield important insights into the number of police agencies that can profitably use the hypercube model for beat design.

Additional comparisons were performed with the Pasadena data to investigate the effects on hypercube accuracy when the size of the data base is increased by including data from tours which contain different numbers of units or different beat configurations. Both of these comparisons are discussed below.

- Number of units - The baseline Pasadena comparisons use data describing field performance statistics for tours with the same number of units deployed in the same beat configuration. Additional comparisons were made to examine the effects of using input data based on tours with the same number of units, but not necessarily the same beat configuration. On the night watch, for example, the eight-unit baseline configuration for Pasadena is based on nine tours. Including all eight-unit tours on the night watch, regardless of configuration, adds two tours. Similarly, using all nine-unit tours on the night watch increases the number of tours from 9 to 13. As a result, composite hypercube estimates, based on all eight- and nine-unit tours on the night watch, are based on 24 rather than 18 tours.

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*The composite Pasadena results are based on only 322 incidents, an average of 2.4 calls per reporting area. In contrast, the 10 percent sample discussed above for St. Louis County contained 536 incidents, an average of 4.7 calls per reporting area.

• All watch data - The second variation examined expanded the data base to include all tours for each watch. With this option, hypercube estimates based on a fixed number of units and configuration are compared with data reflecting tours with differenct numbers of units and a variety of beat configurations.

The number of tours and incidents used in each comparison with these options are shown in Table 4-23. The baseline Pasadena data are identified as the configuration level under the night watch (nine tours with the eight-unit configuration and nine tours with nine-unit configuration). At the unit level, the night watch results are based on 11 eight-unit tours and 13 nine-unit tours (459 incidents); the day watch results are based on 7 nine-unit tours, 6 ten-unit tours, and 7 eleven-unit tours (815 incidents); and results for the afternoon watch are based on 12 eleven-unit tours and 12 twelve-unit tours (1,401 incidents). Watch level results are based on data from all 38 tours for each watch. The results of the comparisons based on each of these variations for all three watches are shown in tables 4-24 through 4-26.

The following observations are based on these comparisons:

• Workload - Both the regionwide average workload and unit workload estimates become less accurate as the overall workload level of the watch increases (in order of increasing workload, the watches are night, day, and afternoon), and there appears to be no improvement in workload estimates with larger sample sizes. Discussions with department staff indicated that less accurate workload estimates for the busier watches may reflect the "unofficial" practice of stacking calls at the beat level. The assessment comparisons for the probability of saturation seem to support this suggestion. Despite threefold increases in the hypercube estimate of the probability of saturation from the night to afternoon watch (the afternoon watch workload was approximately three times greater than the night watch workload), the empirical values for the probability of saturation remain almost the same.

• Cross-beat dispatching - In general, the accuracy of hypercube cross-beat dispatching estimates at the regionwide, beat, and unit levels is very bad. Increasing sample size appears to have little effect on accuracy except for the rank difference sums for beat level estimates.

• Travel time - At both the beat and unit level, the hypercube estimates become more accurate as sample size increases.

Table 4-23

NUMBER OF TOURS AND INCIDENTS BY COMPOSITE LEVEL AND WATCH, PASADENA ASSESSMENT DATA

	Watch									
	Night			Day				Afternoon		
	Number of Units			Number of Units				Number of Units		
Composite Level	8	9	Composite	9	10	11	Composite	11	12	Composite
(Beat configuration)	(1112111)	(1112121)	-	(1111221)	(1111222)	(1112222)	-	(1211321)	(1211331)	-
Configuration[a]										
Number of tours	9	9	18	-	-	-	-	-	-	-
Number of incidents	165	157	322	-	-	-	-	-	-	-
Incidents/reporting area	1.23	1.17	2.40							
Unit[b]										
Number of tours	11	13	24	7	6	7	20	12	12	24
Number of incidents	225	234	459	274	253	288	815	739	662	1,401
Incidents/reporting area	1.70	1.75	3.43	2.04	1.89	2.15	6.08	5.51	4.94	10.46
Watch[c]										
Number of tours	38	38	38	38	38	38	38	38	38	38
Number of incidents	785	785	785	1,522	1,522	1,522	1,522	2,299	2,299	2,299
Incidents/reporting area	5.86	5.86	5.86	11.36	11.36	11.36	11.36	17.16	17.16	17.16

[a]Composites at the configuration level are based on the weighted average (number of tours) of field statistics compiled for tours with the same number of units and beat configuration.

[b]Composites at the unit level are based on the weighted average (number of tours) of field statistics compiled for tours with the same number of units but not necessarily the same beat configuration.

[c]Composites at the watch level are based on the weighted average (number of tours used at the unit-level) of field statistics compiled for each beat configuration over all 38 tours for that watch.

Table 4-24

COMPARISON STATISTICS FOR THE PASADENA ASSESSMENT DATA AT THE CONFIGURATION, UNIT, AND WATCH LEVEL, NIGHT WATCH, EIGHT- AND NINE-UNIT COMPOSITES

Region Level	Empirical	Hypercube	Difference	Percent Difference
Avg. Workload				
Configuration[a]	0.552	0.559	-0.007	-1.27
Unit	0.568	0.568	0.00	0.00
Watch	0.585	0.577	0.008	1.37
Probability of Saturation				
Configuration	0.0645	0.0532	0.0113	17.52
Unit	0.0588	0.0573	0.0015	2.55
Watch	0.0476	0.0606	-0.0130	-27.31
Cross-beat Dispatches				
Configuration	0.5203	0.4758	0.0445	8.55
Unit	0.4934	0.4833	0.0101	2.05
Watch	0.4790	0.4889	-0.0099	-2.07

Unit Level	Avg. Abs. Difference	Avg. Abs. % Difference	Abs. Rank Difference Sum
Workload			
Configuration	0.0465	8.42	15 (not sig.)[b]
Unit	0.053	9.33	14.3 (not sig.)
Watch	0.0461	7.88	11.4 (sig., 10%)
Cross-beat Dispatches			
Configuration	0.1315	25.28	18.5 (not sig.)
Unit	0.1278	25.90	15.5 (not sig.)
Watch	0.1206	25.18	16.2 (not sig.)
Travel Time-min. (sec.)			
Configuration	1.315(78.9)	31.69	29.5 (not sig.)
Unit	1.302(78.1)	29.86	28.9 (not sig.)
Watch	1.087(65.7)	23.38	25.1 (not sig.)
Beat Level			
Cross-beat Dispatches			
Configuration	0.1945	37.39	17.5 (not sig.)
Unit	0.1527	30.95	15.1 (not sig.)
Watch	0.1244	25.97	13.2 (not sig.)
Travel Time-min. (sec.)			
Configuration	1.195(71.7)	28.80	14 (not sig.)
Unit	1.254(72.2)	28.76	15.0 (not sig.)
Watch	1.139(68.3)	24.49	18 (not sig.)

[a]See the footnotes to Table 4-23 for an explanation of how the composite estimates are computed.

[b]The significance levels are based on critical values for eight units.

Table 4-25

COMPARISON STATISTICS FOR THE PASADENA ASSESSMENT DATA AT THE UNIT AND WATCH LEVEL, DAY WATCH, NINE-, TEN-, AND ELEVEN-UNIT COMPOSITES

Region Level	Empirical	Hypercube	Difference	Percent Difference
Avg. Workload				
Unit[a]	0.852	0.754	0.098	11.50
Watch	0.841	0.758	0.083	9.87
Probability of Saturation				
Unit	0.0688	0.1755	-0.1067	-155.09
Watch	0.0902	0.1797	0.0895	-99.22
Cross-beat Dispatches				
Unit	0.3816	0.6030	-.2214	-58.02
Watch	0.3801	0.6036	-.2235	-58.80

Unit Level	Avg. Abs. Difference	Avg. Abs. % Difference	Abs. Rank Difference Sum
Workload			
Unit	0.100	11.74	26.7 (not sig.)[b]
Watch	0.083	9.87	34.4 (not sig.)
Cross-beat Dispatches			
Unit	0.232	60.80	16.8 (sig., 5%)
Watch	0.230	60.51	16.0 (sig., 5%)
Travel Time-min. (sec.)			
Unit	0.985(59.1)	16.01	17.2 (sig., 5%)
Watch	0.362(21.7)	5.86	10.5 (sig., 1%)
Beat Level			
Cross-beat Dispatches			
Unit	0.239	62.63	15.3 (sig., 5%)
Watch	0.240	63.14	14 (sig., 1%)
Travel Time-min. (sec.)			
Unit	0.924(55.4)	15.02	7.5 (sig., 1%)
Watch	0.379(22.7)	6.13	4 (sig., 1%)

[a]See the footnotes to Table 4-23 for an explanation of how the composite estimates are computed.

[b]The significance levels are based on critical values for 10 units.

Table 4-26

COMPARISON STATISTICS FOR THE PASADENA ASSESSMENT DATA AT THE UNIT AND WATCH LEVEL, AFTERNOON WATCH, ELEVEN-AND TWELVE-UNIT COMPOSITES

Region Level	Empirical	Hypercube	Difference	Percent Difference
Avg. Workload				
Unit[a]	0.916	0.789	0.127	13.86
Watch	0.922	0.789	0.133	14.43
Probability of Saturation				
Unit	0.0610	0.1905	-0.1295	-212.30
Watch	0.0536	0.1903	-0.1367	-255.04
Cross-beat Dispatches				
Unit	0.3906	0.5993	-0.2087	-53.43
Watch	0.3749	0.5968	-0.2219	-59.19

Unit Level	Avg. Abs. Difference	Avg. Abs. % Difference	Abs. Rank Difference Sum
Workload			
Unit	0.1265	13.82	39 (not sig.)[b]
Watch	0.1330	14.42	49 (not sig.)
Cross-beat Dispatches			
Unit	0.207	53.00	33 (not sig.)
Watch	0.218	58.15	28.5 (not sig.)
Travel Time-min. (sec.)			
Unit	0.607(36.4)	10.18	14.5 (sig., 1%)
Watch	0.376(22.6)	6.68	8.5 (sig., 1%)

Beat Level			
Cross-beat Dispatches			
Unit	0.2225	56.97	10 (sig., 1%)
Watch	0.236	62.95	8 (sig., 1%)
Travel Time-min. (sec.)			
Unit	0.821(49.3)	13.76	5 (sig., 1%)
Watch	0.624(37.4)	11.08	2 (sig., 1%)

[a]See the footnotes to Table 4-23 for an explanation of how the composite estimates are computed.

[b]The significance levels are based on critical values for 11 units.

Assessment Conclusions

The following observations about the accuracy and usefulness of the hypercube model are based on the comparisons described above and the data collection experiences of the field test agencies. The assessment activities reported above provide some insights into the strengths and weaknesses of the hypercube model, and highlight features of the model that need further development and evaluation.

In general, the assessment indicates that with sufficient amounts of data, collected and aggregated into appropriate data sets, the hypercube model can provide reasonably accurate estimates (i.e., within 10 percent) for some field performance measures. The results of the assessment activities also indicate, however, that the hypercube model is consistently more accurate in estimating some performance characteristics than others. In order of decreasing accuracy, these are workload, travel times, and cross-beat dispatching. Each of these estimates is discussed below.

- Workload - Both the St. Louis County and Pasadena data sets were used to estimate unit workloads, and for each set, the average absolute difference is less than 10 percent. The relative rankings of both sets of estimates are significant (St. Louis County at the 1 percent level, and Pasadena at the 10 percent level). Despite a very small data base, the Pasadena estimate of workload for the baseline configuration differs by less than two percent from the empirical value. The estimate of saturation probability, however, differs by 17.6 percent. Other runs based on the Pasadena data indicate that as the workload level increases, hypercube estimates for both regionwide workload and the probability of saturation become less accurate. Discussions with department personnel indicated that as the call rate increases, the practice of stacking calls at the beat level also increases.

- Travel times - Travel time estimates for St. Louis County were quite good for both the unit (6.08 average absolute percent difference) and beat (10.28 percent) levels. In contrast, errors in travel time estimates for Pasadena were much higher: 31.69 percent at the unit level and 28.80 percent at the beat unit. Subsequent Pasadena runs based on higher workload levels produced travel time estimates comparable in accuracy to those for St. Louis County. It can be argued that Pasadena travel time estimates for the higher call rates are more meaningful since the ratio of dispatched to administrative workload is higher and, as a result, the empirical data base is less influenced by the estimated location of administrative work. For both the St. Louis County data and the higher-call-rate Pasadena data, the relative rankings of the unit and beat travel time estimates were always significant at either the five or one percent level.

- Cross-beat dispatching - The hypercube estimates for the fraction of cross-beat dispatches at the regionwide, beat, and unit levels were generally inaccurate. On the regionwide level, the error for St. Louis County was 17.38 percent, and for the higher-call-rate Pasadena runs, even larger errors occurred. At the beat and unit level, the average absolute errors usually exceeded 25 percent. Based on these results, it appears that even with relatively "clean" data, hypercube estimates for cross-beat dispatching are not adequate for design or planning purposes. A number of factors may have accounted for these large errors: (1) discrepancies between the idealized dispatching policies used by the model and actual dispatcher activities, (2) the common practice of dispatching two or more units to calls, and (3) the inability of either department to adequately describe the location of patrol units when they are on preventive patrol or administrative assignments.

Both the assessment activities and the experiences of the field test agencies raise serious questions about the ultimate usefulness of the model to the law enforcement community. These questions are: (1) Is the effort required to collect the appropriate input data to run the model both feasible and acceptable to most police agencies? (2) Can present model limitations with regard to administrative (or non-CFS) workload, multiple unit dispatches, priority calls, and travel barriers be eliminated without significantly increasing the amount of input data required? and (3) Do hypercube dispatching policies accurately reflect the operational dispatching practices of most police agencies?

Drawing together all of the assessment findings discussed above, the following general observations appear to be most important:

- Model accuracy - The relatively high accuracy of hypercube estimates for workload and travel times is noted above. Although hypercube estimates of cross-beat dispatching were found to be less accurate, the hypercube model may yield potentially useful estimates of patrol field performance characteristics if enough data, adequately screened and prepared, is available. The qualifications placed on the input data, however, may represent a serious defect of the model. The assessment data used for both St. Louis County and Pasadena were carefully collected, screened, and prepared in order to have as good a data base as possible from which to make reliable assessment judgements. It is not unreasonable to suggest that the effort expended to sanitize the input data for the assessment activities was far greater than most police agencies will be prepared to expend in order to use the model. Hence, the results obtained with this data are, at a minimum, equal to and, more likely, superior to the kinds of results that will be obtained by future users of the model. To date, little evidence is available to indicate what kind of accuracy loss can be expected as the input data become less reliable. The additional Pasadena runs suggest that estimate accuracy may improve at first as the size of the data base is increased at the expense of data consistency. Eventually, however, the advantages of a larger data base are overcome by the inclusion of empirical data that does not correspond to the number of units and beat configuration of the corresponding hypercube runs. Observation of the field test agencies strongly suggests that few departments will be willing to do more than segregate the data by time of day, particularly if the data screening process involves more data preparation and additional hypercube runs.

- Data collection effort - Few police agencies have all of the data required for the hypercube model in an easily accessible and useful format. This is particularly true if an attempt is made to use the model to design beat configurations with consistent data sets (i.e., data drawn from tours with the same hours, the same number of units, and the same beat configuration). The field test project clearly demonstrates that data collection activities can require days and weeks of effort. The questionable accuracy of the model used under the conditions discussed above, and the considerable data collection effort required, raises the issue of whether the benefits of the model justify the cost of using it.

- Model limitations - The assessment activities uncovered many limitations in the current version of the hypercube model. Some of these have been cited by other investigators, and in other parts of this report. Others, however, have been largely ignored to date because their implications were not clear. The results of the assessment in particular, and the field test project in general, indicate that the following operational features should be incorporated into the model:

  - explicit modelling of administrative or non-CFS workload,
  - multiple unit assignments for single calls,
  - call priorities, and
  - call stacking at the beat level.

Implementation Assessment

Implementation validity refers to an assessment of the overall response of the real world to the solution suggested by a model under investigation. In this section, the implementation validity of the hypercube model is examined in terms of the following questions:

- What did each field test agency do with the hypercube model during the field test project? and
- What results have been achieved by departments which implemented a beat configuration based on a hypercube analysis?

Both of these questions are discussed below.

Field test activities. Use of the hypercube model by each of the field test agencies is described in the case studies in Chapter II of this report; and a summary of the participation level of each department is presented in Table 2-2. All but one of the field test departments examined all or part of their current beat configurations. Five of the departments analyzed alternative beat structures, and three designed a complete set of new beat configurations. New beat designs were implemented in Frenso, Burbank, and St. Louis County (in two of five precincts).

In discussions with personnel of the five departments which did not design new beat configurations for their departments, the following reasons were identified for limited use of the hypercube model:

- difficulty in obtaining the required input data, and the effort required to collect and prepare the data;
- absence of any perceived need to change the existing beat configuration; and
- a belief that in its present state, the hypercube model cannot adequately model real patrol operations; the most commonly cited limitations were (1) no call priority system, (2) assumption of only one unit per call, (3) no explicit treatment of non-CFS workload, and (4) procedure used to compute travel times.

Field test implementations. As indicated in Table 2-2, three departments implemented beat plans designed with the hypercube system. Although none of the departments initiated significant follow-up evaluation activities to assess the advantages of the new plans, some post-implementation results are available. Each of the three departments is discussed below. (A detailed description of the beat design activities in these departments during the field test project is presented in Appendix A.)

Fresno, California - Preliminary results from Fresno give several indications that the new beat plan, implemented on November 3, 1976, has improved several areas of patrol operation. These improvements are:

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

- The number of calls held over at the end of the busiest shift decreased significantly. Under the old plan as many as 45 calls for service were being held. Under the new plan, the number held over seldom exceeds five.

- Average travel time to calls for service decreased significantly. The average travel time during the first three months under the new plan was 3.8 minutes less than the average travel time during the ten months preceeding implementation of the new beat plan.

- Implementation of the beat plan designed with the hypercube model avoided the need to hire additional officers, a course of action management had previously assumed would be necessary. Estimated savings in salaries and fringe benefits were $200,000 a year.

Despite these impressive results, it is difficult to know what portion of these benefits are directly attributable to the hypercube model. It can be argued that the conditions in Fresno prior to the hypercube analyses were such that almost any reasonable change in manpower allocation by time and geography would have produced some beneficial results. In addition, paralleling implementation of the new beat plan, the department initiated use of a sophisticated CAD system for dispatching patrol units. The interaction effects of this system and the new beat plan are virtually impossible to identify.

Burbank, California - The department implemented a new beat plan based on a hypercube analysis in October 1976. This change represented the first major revision in the beat structure in 15 years. A comparison of several patrol and dispatching measures based on the old and new beat plans is presented in Table 4-27.

Table 4-27

COMPARISON OF PRE- AND POST-IMPLEMENTATION PATROL AND DISPATCH PERFORMANCE STATISTICS, BURBANK, CALIFORNIA

Performance Measure	Old Beat Plan (N=1,457)[a]	New Beat Plan (N=1,772)[b]
• Dispatch time (min.)	6.3(N=1,098)	9.0(N=1,062)
• Travel time (min.)	5.7(N=948)	5.7(N=893)
• Service time (min.)	31.1(N=925)	28.2(N=988)
• Fraction of cross-beat dispatches (%)	46.7(N=1,380)	42.2(N=1,447)

[a]Based on a five percent sample of all dispatched incidents in Burbank from May 1, 1975 through February 10, 1976.

[b]Based on a 50 percent sample of all dispatched incidents in Burbank during October 1976.

These results indicate that while the overall travel time remained the same, the fraction of cross-beat dispatches declined from 46.7 percent to 42.2 percent. During the same time that the new beat plan was implemented, the department also began using civilian dispatchers. This change may have accounted for the significant increase in dispatch time. Despite use of the model to design new beats, personnel at the Burbank department indicated that it is unlikely that the department will use the model again in the near future. The reasons for this decision are: (1) the stable workload pattern in Burbank does not require frequent beat changes, and (2) the civilian who was trained in the use of the model left the department shortly after completing the hypercube analysis.

St. Louis County - The St. Louis County Police Department implemented new beat plans based on hypercube analyses in two precincts in April 1976. Favorable reactions to the beat plans led the department to obtain copies of the hypercube programs for installation on their own computer system. The department has used these programs to analyze its manpower allocation policies and beat configurations in all five precincts; and based on these analyses, new beat plans are scheduled for implementation in all precincts in January 1978.

Conclusions. Use of the hypercube model by the field test agencies highlighted many implementation difficulties. Technical limitations of the model which may limit it's wide-spread use are:

- the unavailability or inaccessibility of input data required to obtain reasonably accurate hypercube estimates;
- the effort required to collect enough input data to yield reliable results;
- the amount of training required to run a model which may be used infrequently; and
- a lack of confidence in the model due to its limitations in modelling non-CFS work, priorities, multiple unit assignments, and in computing travel times.

Other implementation barriers related to the cost and use of a computer model as large and complicated as the hypercube system are discussed in the following chapter.

CHAPTER V

TECHNOLOGY TRANSFER

A. Introduction

This chapter reviews the technology transfer accomplishments of the research team. Topics discussed include the following:

- information dissemination - creation of an awareness within the law enforcement community of hypercube's availability and capabilities, and of the potential benefits which can result from its use;

- software dissemination - development of avenues for assuring the future availability of the hypercube computer programs, and for encouraging police departments to use them;

- technical assistance - identification of the need for expert assistance among police users of hypercube, and potential sources for obtaining such assistance in the future; and

- training - identification of the need for and potential sources of training in use of the hypercube programs.

Each section includes information on accomplishments to date, the need for additional technology transfer efforts, and promising alternatives for meeting these needs.

B. Information Dissemination

Informing potential users of the availability and capabilities of the hypercube programs, and of the potential benefits which can result from their use, is a far more difficult task than may be perceived at first glance. If hypercube were a proprietary, commercial product, such communication would be an essential part of the marketing effort. Although "information dissemination" is less assertive and less well funded in the realm of public technology transfer, the problems are the same. The right information must reach the right people and organizations at the right times, and adequate follow-up must be available to respond to the resulting sparks of interest before they die. A small number of journal articles and conference papers are clearly inadequate.

With this perspective in mind, the TIPPA research team undertook the task of information dessemination during the project through direct contact with interested organizations, publication of journal articles and announcements, and presentations about hypercube at meetings and conferences. These activities are outlined below.

Institutions, Organizations, and Programs Receiving Information on Hypercube

1. Organizations represented on Project Advisory Board

Through the participation of their representatives on the Project Advisory Board for this study, the following organizations were apprised of hypercube's capabilities and had an opportunity to offer suggestions regarding technology transfer:

California Innovation Group (CIG)
International Association of Chiefs of Police (IACP)
International Conference of Police Associations (ICPA)
Police Foundation

2. Public technology transfer organizations and programs

Building on the research team's favorable experience in working with CIG during the field test, and on the expanding capabilities and number of other public technology transfer organizations, the team made contact with the organizations and programs listed in Table 5-1. Each organization received

Table 5-1

PUBLIC TECHNOLOGY TRANSFER ORGANIZATIONS CONTACTED

New England Innovation Group
National Governor's Conference - Science and Technology Project
National Conference of State Legislatures - Office of Science and Technology
Public Technology Incorporated (PTI) - Urban Technology System
National Conference of State Criminal Justice Planning Administrators - technology transfer program
Law Enforcement Assistance Administration (LEAA) - Office of Technology Transfer
International City Management Association (ICMA) - innovations evaluation and dissemination program
Other organizations listed in "Directory of Federal Technology Transfer"
Rand Corporation - criminal justice planning models dissemination program

basic information about hypercube and relevant materials presently available or being completed.

3. Law enforcement operating, planning and service organizations

A wide range of law enforcement operating, planning, and service organizations were sent information about hypercube. These are listed on Table 5-2.

4. Persons having obtained copies of the hypercube programs

TIPPA obtained a complete list of persons who have obtained copies of the hypercube programs from the two dissemination sources in operation at the time of this project: M. I. T. and the Rand Corporation. Information about hypercube's expanded capabilities and the implementation aids to be produced by the present project was sent to all, along with a questionnaire about user experience to date. The persons reached in this manner were mainly police departments, consulting firms, university-based individuals, and criminal justice planning agencies.

Table 5-2

LAW ENFORCEMENT ORGANIZATIONS CONTACTED

LEAA state planning agencies
Police chiefs' associations
Police officers' associations
Police officer standards and training commissions
LEAA regional offices
Police departments other than field test agencies: Brea, Orange County, and San Diego Sheriff's Office, California (participants in project orientation meeting or training program)

5. Persons requesting copies of TIPPA research reports on hypercube

TIPPA presented research papers on the hypercube field test project at three national professional society meetings, discussed below. In response, numerous requests for information about hypercube were received from police organizations in the United States and abroad, publishers of police periodicals, private industry, university research programs, government agencies concerned with emergency services other than law enforcement, and consulting firms. Copies of the research papers were sent to all.

6. Information dissemination services

Contact was made with the National Criminal Justice Reference Service, National Referral Center of the Library of Congress, and National Technology Information Service regarding procedures for dissemination of documentation produced by the field test project. In each case such dissemination is feasible and can be accomplished with a minimum of effort when the documents are available.

7. Software dissemination programs (see section below)

8. Technical assistance programs (see section below)

9. Training programs (see section below)

Publication of Articles, Announcements, and Other Communications About Hypercube

TIPPA distributed two types of information to appropriate printed media outlets: material suitable for articles about hypercube, and material about a test presentation of the hypercube training seminar open to outside participation. Additionally, TIPPA researched the possibility of future articles about hypercube when the field test is completed.

1. TARGET (ICMA)

This publication deals with innovative criminal justice programs, reaching 30,000 law enforcement and criminal justice professionals each issue. The lead story of the March 1977 issue concerned the successful use of hypercube by the Fresno Police Department in conjunction with the field test project. TIPPA proposed the article to TARGET and supplied the information on which it was based.

2. Law enforcement newsletters

Information about hypercube and the hypercube training program appeared in Crime Control Digest (October 25, 1976), Training Aids Digest (December 1976), Law Enforcement News (December 21, 1976), and Criminal Justice Newsletter (December 1976), as a result of news releases issued by TIPPA.

3. Police Chief

Norman Darwick, IACP executive and hypercube project advisory board member, has indicated that the Police Chief will accept an article on the hypercube field test project. A good issue for publication would be the October 1977 issue which will focus on innovative technology, and which will receive maximum dissemination since it is the IACP's annual meeting issue.

4. The Law Officer

Robert Kliesmet, ICPA vice president and hypercube project advisory board member, has indicated that The Law Officer will accept an article on the hypercube field test project, with emphasis on its implications for police unions and police officers' associations. The magazine reaches over 180,000 officers in the United States.

5. Newspaper articles

Two newspaper articles were published in Fresno describing the use of hypercube there:

"A New Beat For Police By Computer", The Fresno Bee, October 28, 1976

"Fresno Pioneers New System to Improve Police Services", The Fresno Guide, November 3, 1976

6. Internal report of the Fresno Police Department

A report summarizing participation in the field test project and discussing the benefits derived from use of hypercube was written by staff of the Fresno Police Department. Entitled, "Beat Design and Manpower Deployment System," by Deputy Chief James Packard, the report was distributed within Fresno and to other police departments requesting information about the hypercube project.

7. National Criminal Justice Reference Service announcements

TIPPA assisted Dr. Jan Chaiken of the Rand Corporation in arranging publication of a Selective Notification of Information (SNI) announcement of the availability of Rand reports on the hypercube model and program (about 18,000 persons received this SNI). TIPPA also arranged for publication of an SNI on its one-week hypercube seminar held January 31 - February 4, 1977 (about 38,000 persons received this SNI).

8. Office of Criminal Justice Education and Training, LEAA

This organization coordinates training and personnel development for LEAA. In response to a TIPPA request, its director issued a memorandum in November 1976 on hypercube's availability and related training materials to all LEAA federal regional offices. TIPPA has since been contacted for additional information on hypercube by a number of the memorandum's recipients.

9. Urban Regional Information Systems Association (URISA) Newsletter

A TIPPA press release on the hypercube programs and related training resulted in a short article in the URISA Newsletter of October 1976.

10. IACP annual equipment directory

TIPPA prepared and submitted a product announcement to be published in the first issue of the IACP Equipment Technology Center's annual equipment directory. The announcement, describing hypercube and explaining how to obtain related materials, should reach administrators and purchasing agents in 3,000 U.S. law enforcement agencies.

11. Mathematica, Inc. article on hypercube

An article on the hypercube programs, aimed at city management personnel, has been written by Mathematica, Inc. under contract to NSF's RANN office, as part of a program to publicize results of RANN projects. The article is intended for inclusion in a RANN magazine whose publication is now under consideration at NSF. If the RANN magazine is not published, Mathematica has indicated to TIPPA that it would welcome use of the article in any future hypercube dissemination program; it appears appropriate for ICMA's Public Management magazine.

12. Publications related to software, technical assistance, and training

Many of the organizations identified for the distribution of hypercube software, provision of technical assistance, and training, publish periodicals, bulletins, and training announcements which reach thousands of potential hypercube users. This dissemination channel can be activated if additional effort is devoted to promoting the cooperation of these organizations.

Dissemination of Information at Meetings, Conferences, and Training Programs

1. RANN 2 Symposium

TIPPA designed and operated an exhibit on the hypercube field test project at the RANN 2 Symposium held in Washington, D.C. in November 1976. Over 1,000 government, university, and private industry personnel attended. TIPPA produced a six-minute film on the project which, along with the rest of the exhibit, is available for use at future meetings. A summary of the project appeared in the program guide, and will be published in the proceedings. To facilitate communication with Washington-based organizations to whom TIPPA had been directing information on hypercube, numerous organizations were telephoned by TIPPA in advance of the meeting and invited to send representatives to the exhibit (see Table 5-3 for a list of those contacted). Many subsequently attended.

2. <u>ICPA annual meeting</u>

A member of the TIPPA research team presented a talk on the hypercube programs and their possible implications for police unionism at the July 1976 annual meeting of the International Conference of Police Associations in Palm Springs, California. Officers of police associations representing over 180,000 police officers in the U.S. and other countries were in attendance.

Table 5-3

ORGANIZATIONS INVITED TO RANN 2 SYMPOSIUM EXHIBIT

National League of Cities, Criminal Justice Project
NTIS Computer Products Division
Office of Policy Development and Research, HUD
Office of Criminal Justice Education and Training, LEAA
Division of Technology Transfer, LEAA
Police Foundation
University of Maryland, law enforcement programs
American University, National Institute on Law Enforcement Management
IACP Police Management and Operations Division
National Conference of State Criminal Justice Planning Administrators
Training Division, LEAA
Crime Control Digest
Police Division, LEAA
Public Technology, Inc., software exchange
ICMA Innovation's Program, and Police Research Program
ICPA National Headquarters
Public Administration Service, Technical Assistance Project

3. Papers on the hypercube field test presented at professional society meetings

The following three papers were presented by TIPPA staff members at meetings of the Operations Research Society of America and The Institute of Management Sciences:

"Evaluation of Police Sector Design Procedures," Las Vegas, November 1975

"Progress in Field Testing the NSF-MIT Hypercube Police Beat Design Methods," Philadelphia, April 1976

"Use of the Hypercube Model in Field Tests in California Police Departments," Miami, November 1976

4. Urban and Regional Information Systems Association (URISA) Workshop, August 1976

URISA presented a workshop on Law Enforcement and Criminal Justice Information Systems at its annual meeting in Atlanta. TIPPA worked with the workshop coordinator to secure inclusion of hypercube in the program. The presentation was made by Dr. Roger Elliot of Texas A&M University, who has headed an LEAA-funded project which translated the hypercube program from PL/I to COBOL to make it more accessible to Texas police agencies.

5. IACP annual meetings

Efforts were made to arrange for a demonstration of the hypercube programs and a portable data terminal at the annual meeting of the International Association of Chiefs of Police in Miami (September 25-30, 1976). Unfortunately, IACP's plans for exhibits and presentations at the meeting began early and no exhibit space or presentation openings remained by May 1976 when TIPPA began its inquiries. Despite assistance from Norman Darwick, it was not possible to make satisfactory arrangements and the project was temporarily dropped. Up to 7,000 police executives have attended previous annual meetings, visiting the exhibits of hundreds of vendors. The next annual meeting will be held in Los Angeles in October 1977, at which time it is hoped that an exhibit will be provided.

6. Association of Police Planners and Research Officers (APPRO) annual meetings

This organization brings together from 150 to 200 police planning and research personnel for three-day annual meetings. The March 1977 meeting included a presentation on law enforcement technology transfer by Gerald Miller, former CIG science advisor for San Diego and participant in the hypercube field test project. TIPPA supplied him with material on hypercube for inclusion in his presentation.

7. Police planners' training programs

During the course of the project Nelson Heller presented introductory material on hypercube to approximately 200 police planners and executives attending management short courses at the Traffic Institute, Northwestern University. Independent of the TIPPA project, Dr. Richard Larson presented material on hypercube at M. I. T.'s annual "Analysis of Urban Service Systems" short course whose participants included police planners and executives.

C. Software Dissemination

Project activities related to software dissemination are summarized below. Potential impediments to successful future dissemination are also identified.

Identification of Software Exchanges and Other Programs For Dissemination of the Hypercube Software

CONTINUED

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1. <u>NTIS Computer Products Division</u>

NTIS is one of the prime software distributors for computer programs produced under government funded projects. For about $60 a software package can be entered into the distribution library. Newly-acquired packages are announced in NTIS publications such as <u>Urban Technology</u> and <u>Problem Solving Information for State and Local Governments</u>. A catalog entitled "Special Software for Local Governments" is published and periodically updated by the Computer Products Division. As part of an HUD technology utilization project, the Rand Corporation has entered an earlier version of the hypercube program in the NTIS library. In response to a TIPPA inquiry, NTIS has indicated that it would be pleased to add the interactive software from the field test project to this library.

2. <u>National Clearinghouse for Criminal Justice Information Systems (NCCJIS)</u>

This LEAA-funded project, operated by Search Group, Inc. of Sacramento, California, became operational in the Fall of 1976. It is intended to serve as a software dissemination service for programs relevant to law enforcement and criminal justice operations, and expects to publish a newsletter and offer technical assistance as well. A member of the TIPPA research team visited NCCJIS in January 1977 to present a talk on hypercube to the professional staff. The project director expressed a keen interest in adding hypercube to their dissemination program.

3. <u>Center for Advanced Computation (CAC)</u>

The Center for Advanced Computation is located at the University of Illinois at Champaign-Urbana. It is presently supplying remote access time-shared data processing services to LEAA's National Center for Criminal Justice Information and Statistics, and, with this organization, is studying the feasibility of operating a national computer-based data and software archive. Such an archive could make programs such as hypercube available to law enforcement agencies via remote access time sharing in the same manner as the National CSS system implemented by TIPPA. The CAC also envisions conducting training programs in software usage and publishing a newsletter. Preliminary estimates of CAC data processing costs indicate that they might be considerably lower than commercial systems. In February 1977 TIPPA's executive director visited the National Center for Criminal Justice Information and Statistics to discuss with its staff the dissemination of the hypercube software in this manner.

4. NASA's Computer Software Management and Information Center (COSMIC)

One of the nation's largest software libraries of engineering analyses and other programs is maintained by NASA at COSMIC, located at the University of Georgia. Programs developed by other government agencies, as well as by NASA, are included. COSMIC serves as a clearinghouse for the transfer of these programs to industrial and other users. Some of the 1600 programs now available deal with law enforcement and other public service operations. To announce new programs NASA publishes a quarterly catalog called the Computer Programs Abstract Journal, which is available by subscription through the U.S. Government Printing Office.

5. National CSS, Inc.

The interactive hypercube software package developed by TIPPA for the field test project includes supportive software for data and program manipulations which will operate only on the National CSS system. This interactive package will be available on tape from TIPPA and possibly from other sources. Future users will mail a copy of the tape to National CSS to have it put on the system for the period of usage. If sufficient demand for the package materializes, National CSS may decide to make it a "local product." In that case, the software would be resident in the National CSS program library, and would be supported with some form of technical assistance.

6. Massachusetts Institute of Technology - Hypercube Research Project

Dr. Richard Larson will continue to make copies of the hypercube software available for the cost of preparing them.

7. Public Technology, Inc. (PTI) software library

PTI operates a software library containing computer programs of use to local and regional governments for the management of public services. For some programs (e.g., a fire station location package), PTI offers installation and technical assistance services. PTI publications announce new software acquisitions. In response to a TIPPA inquiry, PTI has expressed interest in adding the hypercube software to its library.

8. Private management consulting firms

Some of the present owners of the hypercube software are private management consulting firms which have used hypercube for work with client police agencies (e.g., Urban Sciences, Inc.

of Wellesley, Massachusetts working with the Newark, New Jersey Police Department; Public Management Services, Inc. of McLean, Virginia working with the Toledo, Ohio Police Department; and Public Systems Evaluation, Inc. of Cambridge, Massachusetts working with the Wilmington, Delaware Police Department). These firms may implement hypercube for future clients, if requested, but experience to date indicates that the analyses are often done on the firm's own computer without implementation at the client agency.

9. Regional criminal justice information systems

Some regional information systems may choose to implement the hypercube software at the request of one of their participating police departments. For example, as a result of participation in the field test project, the St. Louis County Police Department (via REJIS of St. Louis) and San Diego Police Department (via ARJIS of San Diego) plan to implement the COBOL version of the non-interactive program. None of the regional systems known to TIPPA supports PL/I or remote access time sharing of the nature required by the monitor program; consequently, interactive features of the hypercube software cannot be used.

10. Urban Information Systems Interagency Committee (USAC)

The USAC program is an effort to sponsor research and development of transferable and operationally based municipal information systems. Six cities were selected in 1970 to develop transferable information system modules. The Law Enforcement Subsystem - Municipal COBOL Computer Programs Module was developed by Wichita Falls, Texas, and is now available from NTIS. This module is basically a management information system tied to monitoring routine police operations. Conceivably, the hypercube software could be made compatible with this module, thereby making it accessible to cities which implement the USAC package. Such a tie-in would also provide an information dissemination channel for hypercube, via the present network of USAC participants.

11. TIPPA

The Institute for Public Program Analysis will maintain the hypercube software in its program library and provide tape copies for sale at cost. It will also offer related technical assistance.

12. Texas A&M University

As described in Appendix C, Texas A&M University will distribute the COBOL version of hypercube which it developed along with related software of its Police Officer Deployment System (PODS).

Need for Changes in the Hypercube Software to Facilitate Dissemination

During the field test a number of problems and related potential improvements were identified. Those problems which could seriously hinder dissemination of the hypercube software are briefly discussed here. See Chapter IV for a more detailed discussion.

1. PL/I is not supported by police data processing centers.

The interactive monitor program and most versions of the non-interactive hypercube program are available only in PL/I, a programming language not supported by most police data processing centers. PL/I is used mainly for scientific applications not normally needed by local governments. Additionally, the PL/I compiler is a proprietary product of IBM which must be rented from it. Consequently, the PL/I hypercube software can only be run for police users on non-owned equipment such as might be available at a local university or commercial vendor of data processing services.

2. COBOL hypercube software has limited capabilities.

Many police data processing facilities support COBOL and should be able to implement the COBOL hypercube software providing sufficient core storage is available. Such implementation has the significant benefit of being cost-free or relatively inexpensive for most police departments when compared to the cost of commercial services. The COBOL program includes only the approximate hypercube model and, therefore, omits capabilities requiring the exact model, such as AVL (automatic vehicle location) and VST (variable patrol unit service times).

3. Most police departments have no budget for outside data processing.

Police agencies customarily obtain needed data processing services from an in-house computer, a regional information system, or a city-owned computer. Obtaining funds for the purchase of other data processing services, such as commercial time-share data processing, usually involves considerable selling and red tape, and in some cases, may not be possible. This circumstance will severely limit future usage of the National CSS interactive hypercube package by police departments. Unfortunately, this implies that the benefits of the interactive monitor and supportive software will be available to few users.

4. Preparation of input for the non-interactive hypercube software is difficult for persons not familiar with data processing.

Police planners participating in the field test project who had no previous exposure to computers, and even many who were familiar with data processing, expressed a strong preference for use of the interactive system over non-interactive systems. The interactive system offers tutorial and error correction capabilities, as well as immediate results and easier management of program runs. The non-interactive program requires rigidly formatted input, as described in a program user's manual not easily understood by police planners (especially those without prior data processing experience). One consequence is that the non-interactive program is less useful than the interactive one for teaching purposes.

5. If hypercube input data can be derived from the USAC law enforcement module an interface program will probably be required.

As indicated above, the USAC law enforcement module provides basic data management for police agencies. If owners of the module can compile hypercube input data easily they will have additional motivation to implement hypercube. A study will be required to determine the feasibility of using the USAC program to compile hypercube input, and to ascertain what additional software will be required to accomplish this.

6. Hypercube needs to account for travel barriers, priorities, and non-cfs work.

Police planners participating in the field test found that field operations personnel were concerned that hypercube does not account adequately for travel barriers, call priorities, and non-called-for-service work. Some of the planners themselves felt that without incorporation of these factors into hypercube's calculations, hypercube output would not be reliable. The methodology for including these considerations into hypercube has been developed by the M. I. T. research team, but has yet to be programmed.

7. Hypercube needs to be tied-in with Patrol Car Allocation Model (PCAM)

Field test results suggest that most of the police departments which can benefit from using hypercube, can use it most effectively in conjunction with PCAM. PCAM has the following features lacking in hypercube: (1) it treats all days of the week, watches, and geographic regions simultaneously, (2) it is prescriptive, providing optimal allocations of patrol resources by time and place according to any of a set of available objective functions, (3) it is very inexpensive to run, and (4) it readily accounts for non-cfs work, and for up to three classes of call priorities. Consequently, patrol district redesign can be accomplished at lower cost and in less time if PCAM is used first to determine the number of cars required by time and place, and then hypercube is used to lay out the patrol district boundaries. Although the entire job can be done with hypercube, it is a more cumbersome, costly, and time consuming process. Proper mating of PCAM and hypercube will require a planning and programming effort, particularly if common input data are to be accessed by both programs.

Need for Supportive Services to Promote Software Dissemination

The dissemination of the hypercube software into the nation's law enforcement community will be severely limited if adequate training, technical assistance, and information dissemination are not available. Field test experience confirms the need for comprehensive training (despite the availability of program user's manuals and other documentation), a minimal level of technical assistance for data collection and use of the software (such as the over-the-phone service offered by TIPPA during the field test), and an active information dissemination program involving the interest groups and government programs which influence police planning. This suggests the need for continuing coordination and support efforts, particularly during the next two to three years when adequate materials for software, training, technical assistance, and information dissemination will be available for the first time.

D. Technical Assistance

This section identifies potential sources of hypercube technical assistance, as well as related needed improvements in the hypercube system, and supportive services which would facilitate the future availability of technical assistance.

Identification of Potential Sources of Technical Assistance for Hypercube Users

1. National Clearinghouse for Criminal Justice Information Systems (NCCJIS)

As described earlier, this LEAA-funded program operated by Search Group, Inc. of Sacramento, California plans to offer limited technical assistance to support the software it disseminates, and to provide referral information regarding other sources of technical assistance.

2. Center for Advanced Computation (CAC)

CAC is another potential disseminator of the hypercube software which could conceivably offer technical assistance to users of the interactive software (if CAC implements this on its computers and markets it to the law enforcement community). If present planning comes to fruition, CAC might be partially supported by LEAA in such an endeavor.

3. LEAA technical assistance programs

LEAA currently supports at least three technical assistance programs which might be of use to police departments employing the hypercube programs:

National Center for Criminal Justice Planning and Architecture (NCCJPA). This program based at the University of Illinois at Champaign-Urbana develops and publishes planning guidelines, and provides technical assistance to criminal justice agencies. Since inception over 300 law enforcement agencies in 40 states have been aided. In response to a TIPPA inquiry, the Center's director has expressed interest in including hypercube in their program. NCCJPA also has an active information dissemi-national program which could benefit hypercube, including an annual national symposium, training workshops, and publications (e.g., technology transfer reports summarizing useful innovations or widely applicable plans).

Westinghouse Corporation and Public Administration Service. These two firms supply criminal justice management and planning technical assistance at no cost to client agencies. Agencies desiring their services must have their request approved by their state law enforcement planning agency. To respond to a request involving use of the hypercube software, it is likely that these firms would seek outside consultants with the appropriate expertise rather than develop and support such expertise within their own staffs.

Science Advisor Program. The National Institute of Law Enforcement and Criminal Justice's Office of Technology Transfer is presently operating this program on an experimental basis, having placed science advisors on the staffs of law enforcement planning agencies in three states. These advisors could conceivably develop expertise in hypercube and facilitate its use by police departments in their states. However, given the advisors' many responsibilities and the many police departments in each state, they could be of only limited assistance to individual departments.

4. Consulting firms and police service organizations

As mentioned earlier, private consulting firms such as Urban Sciences, Inc., Public Systems Evaluation, Inc., and Public Management Services, Inc. have already used hypercube in work with client police agencies, and could conceivably offer technical assistance services in the future. Organizations like IACP's Police Management and Operations Division, and the Public Administration Service regularly market management consulting services to police agencies but have no expertise or experience with hypercube. Given an adequate demand, they could develop the expertise or bring in outside consultants when needed.

5. Public technology transfer organizations

As part of its technology transfer program, NASA has established technology applications teams at the Stanford Research Institute and at Public Technology, Inc. These groups visit agencies in the public sector to determine what significant problems might be solved by the application of NASA technology. One area of concentration to date has been public safety. These teams might possibly have an interest in hypercube, particularly if it were installed in the COSMIC software library. The feasibility of their providing technical assistance to hypercube users is not known. Many other public technology transfer organizations exist (e.g., California Innovation Group, New England Innovation Group, and PTI's non-NASA programs). Field test experience indicates that these organizations prefer to serve as brokers in technology dissemination, linking potential users to sources of expertise, rather than providing technical assistance themselves, because of infrequent demand for such services for programs such as hypercube.

6. The Institute for Public Program Analysis

TIPPA will continue to offer the type of technical assistance provided to its field test police departments, on a cost basis. To minimize this cost, clients will be encouraged to participate in the one-week hypercube training program, making it possible for them to later rely mainly on over-the-phone technical assistance.

Need for Improvements to the Hypercube System to Facilitate Technical Assistance

During the field test a number of potential improvements to the hypercube system were identified which would simplify and lower the cost of providing technical assistance to hypercube users. These are discussed here.

1. Improving the input format for the non-interactive program

The field test indicates that most future police users of hypercube will employ the non-interactive COBOL version. Since this excludes the interactive capabilities of the monitor program (e.g., tutorial and error correcting features), users can be expected to require more technical assistance than needed with the National CSS software used during the project. In the next chapter a recommended manual alternative to the interactive system is proposed, which could restore to the user most of the capabilities presently unavailable in the COBOL program.

2. Developing a tie-in with PCAM

As described earlier, most police departments which can benefit from hypercube can simplify and cut the cost of hypercube use by also implementing PCAM. In this regard, development of an improved tie-in of PCAM with hypercube will reduce the technical assistance services required by hypercube users.

3. Field operations design workshops

Technical assistance costs can be reduced significantly if they can be shared by hypercube users rather than purchased individually. Results of the field test suggest that once graduated from the one-week hypercube training program, police planners might assemble needed input data in their own departments and then reconvene for a one-week workshop. Operators of the workshop would provide computer terminals, software, and technical assistance. Because a small number of workshop staff members could assist several police planners simultaneously, this could reduce technical assistance costs considerably. Also it could speed up the hypercube analyses compared to the time which would be needed by the planners working alone.

Need for Supportive Services to Facilitate the Availability of Technical Assistance

Few of the potential sources of technical assistance for hypercube users presently possess the expertise needed to provide this service, and few of the potential users are aware of how to go about locating needed technical assistance. Results of the field test suggest that the following supportive services, if implemented, could alleviate these problems.

1. <u>Training program for technical assistance personnel</u>

The dissemination and use of hypercube could be given a significant boost if a no-cost training program could be offered to representatives of organizations committed to providing technical assistance. For relatively little cost such a program would provide a cadre of hypercube experts in the organizations likely to be most effective in disseminating hypercube.

2. <u>Registration of technical assistance sources with referral services</u>

The National Referral Center (NRC) of the Library of Congress provides a free referral service to members of the public seeking sources of expertise in any area of science or technology. Sources of technical assistance for hypercube can register at no cost with the NRC. Since many police departments will be unaware of the NRC, the sources must also make themselves known to local, state, and federal law enforcement planning agencies. For example, the state law enforcement planning agency in Kansas publishes a catalog of technical assistance sources classified by type of service.

3. <u>Tie-in of technical assistance with training and software dissemination programs</u>

Technical assistance costs can be reduced if the suppliers are also involved in training and software dissemination. For hypercube, training is a form of technical assistance--the better trained the user, the less his need for assistance. Similarly, effective software dissemination will require at least a minimum level of technical support.

E. Training

Potential sources of hypercube training are identified below. Additional needs in the areas of support and development are also outlined.

Identification of Potential Sources of Training for Hypercube Users

1. Criminal justice training programs

The "Law Enforcement and Criminal Justice Education Directory" published by IACP lists hundreds of university-based criminal justice training programs. Law enforcement periodicals such as Training Aids Digest, Law Enforcement News, and NCJRS' Selective Notification of Information identify many other organizations providing training programs for police personnel. Using these sources, TIPPA identified 18 programs to which material on hypercube was mailed. Included were an explanation of the forthcoming availability of the hypercube training handbook and a request that hypercube be considered for inclusion in current or future police training programs. The organizations contacted are listed in Table 5-4.

Realizing that there are organizations which do not themselves provide training but exert considerable influence over those that do, TIPPA also directed information on hypercube to such organizations (see Table 5-5).

Table 5-4

CRIMINAL JUSTICE TRAINING PROGRAMS CONTACTED

Center for Criminal Justice, California State University, Long Beach
FBI National Academy
Federal Law Enforcement Training Center
Criminal Justice Department, Washburn University of Topeka
Law Enforcement Programs, University of Maryland
Police Executive Development Institute, Pennsylvania State University
School of Police Administration, University of Louisville
Regional Criminal Justice Training Center, Modesto, California
Annual National Institute on Law Enforcement Management, American University
Center for Criminal Justice Training, Indiana University
Criminal Justice Training Center, University of Wisconsin-Milwaukee
Florida Institute for Law Enforcement, St. Petersburg, Florida
Administration of Justice Bureau, San Jose State University
Criminal Justice Center, John Jay College of Criminal Justice
Institute for Criminal Justice Planning and Evaluation, Florida State University
Criminal Justice Planning Institute, University of Southern California
Police Sciences Division, University of Georgia
Center for Criminal Justice, Case Western Reserve University Law School

Table 5-5

ORGANIZATIONS INFLUENCING TRAINING PROGRAMS

Division of Technology Transfer, Training Programs, LEAA
Office of Criminal Justice Education and Training, LEAA
Police Executive Program, Police Foundation
National Conference of State Criminal Justice Planning Administrators
Training Division, LEAA
Southwestern Association of Criminal Justice Educators, Fort Worth, Texas

2. Professional society meetings

Some professional societies offer training workshops in conjunction with annual meetings and other conferences. In response to inquiries from TIPPA, the following indicated that a workshop on hypercube could conceivably be offered in this manner: ICMA, IACP, and ICPA.

3. LEAA's Executive Training Program in Advanced Criminal Justice Practices

This recently funded program being conducted by the University Research Corporation of Washington, D.C., will be conducting a national training program on managing patrol. In response to a request from the project director, TIPPA has supplied the project with material on hypercube and on the hypercube training handbook.

4. M. I. T.'s "Analysis of Urban Service Systems"

As mentioned earlier, this one-week seminar conducted by Dr. Richard Larson is offered each summer by M. I. T. One day of the program is devoted to an introduction to hypercube.

5. The Traffic Institute

Approximately 100 police planners and executives are introduced to hypercube annually in three courses offered by The Traffic Institute at Northwestern University: Traffic Police Administration Training Program, Principles of Police Management, and Law Enforcement Planning Officers Seminar.

6. IACP training programs

IACP offers a number of training programs for police planners and executives each year, including ones dealing with management, planning, and data processing. These programs are offered at different sites throughout the country and attract a large number of participants. Through Norman Darwick, IACP executive and member of the hypercube project advisory board, and mail and personal contact with other IACP field operations and training personnel, TIPPA has explored the possibility of including material on hypercube in some of these programs.

7. Center for Advanced Computation (CAC)

As described earlier, CAC is studying the feasibility of providing time-share data processing services for criminal justice planning models such as hypercube, and of running training programs to familiarize potential users with the software. Funding for the project is being sought from LEAA.

8. The Institute for Public Program Analysis

TIPPA offered a one-week hypercube training seminar to the law enforcement community at large on an experimental basis January 31 - February 4, 1977. If demand for the seminar is adequate it will be repeated periodically. Materials developed for the seminar, including the training handbook and agenda, will be made available to other criminal justice training programs upon request. These materials can also be used for self-study by individuals who cannot attend a hypercube training program.

Need for Development of Additional Training Resources

The following needs for development of additional training resources were identified during the field test.

1. Use of the non-interactive COBOL program

The present training handbook emphasizes use of the interactive hypercube software in training because of its conversational, tutorial, and error correcting features. Once familiar with the interactive system the student is instructed in the use of the non-interactive program. Use of the interactive software in training increases the cost of the training program, and can be superfluous for users who will work only with non-interactive versions of the hypercube software. A manual alternative to the interactive system is recommended in the next chapter. The training handbook should be revised accordingly.

2. Training materials for PCAM

As discussed earlier, use of hypercube by some police departments will be tied to their ability to use PCAM. Although a user's manual and a related training guide are available for PCAM, this material is not readily understood by police planners unfamiliar with computers and rudimentary algebra. Also, the same formatting problems associated with preparing input for the non-interactive hypercube program apply to the preparation of PCAM input. The methods used to develop the hypercube training handbook could easily be applied to development of a similar resource for PCAM.

3. Continuing evolution of the hypercube software

As additional capabilities--such as those recommended by this project or proposed by Dr. Richard Larson--are added to current versions of the hypercube software, it will be necessary to update the training materials accordingly.

Supportive Activities Required to Facilitate the Availability of Training in Hypercube Use

1. LEAA block grants and other funding for training

Under the Safe Streets Act and its successors, state law enforcement planning agencies receive funds for training criminal justice professionals as part of annual block grants. Much of the training of police planners in recent years has been paid for in this manner. Usually the individual desiring to attend a training program submits information about the program along with a request for funds to his state agency. Consequently, the state agency exerts considerable influence over the type of specialized training received. For this reason TIPPA distributed a package of information on hypercube and hypercube training to all such state agencies.

Police Officer Standards and Training (POST) commissions operating in 46 states also exert considerable influence on in-service training received by police personnel. In most instances police officers accumulate educational credit for POST-certified programs, and promotions or educational salary incentives may be tied to the credits earned. Many POST commissions reimburse tuition and subsistence expenses for approved courses that are successfully completed. Funds for this purpose are derived from subgrants of the state's LEAA block grant, or from income derived from the collection of certain types of fines and penalties (as provided for by state law). Since POST approval of training programs is so important to their success, TIPPA sent each of the 46 commissions information on hypercube and requested that hypercube training be approved.

In order to facilitate future training, a continuing effort should be devoted to promoting the cooperation of the state law enforcement planning agencies and the POST commissions.

2. <u>Memo on hypercube from LEAA's Office of Criminal Justice Education and Training (OCJET)</u>

As mentioned earlier, in response to a request from TIPPA for assistance in the training phase of the technology transfer effort, the director of OCJET issued a memo on hypercube to all federal regional LEAA agencies. As a result, the Denver regional office requested material from TIPPA for use in assessing the feasibility of a regional conference on hypercube, and the Virginia agency asked for material in connection with possible follow-up in that state.

3. Information dissemination regarding TIPPA's hypercube seminar held January 31 - February 4, 1977

As a result of press releases and other information dissemination on TIPPA's seminar, news articles and announcements regarding hypercube and the training program were published by Crime Control Digest, Training Aids Digest, Law Enforcement News, URISA Newsletter, Criminal Justice Newsletter, and NCJRS' Selective Notification of Information. A side benefit of such publications is an increased awareness of hypercube by law enforcement personnel nationwide.

CHAPTER VI

RECOMMENDATIONS FOR IMPROVEMENT, DISSEMINATION, AND INSTITUTIONALIZATION OF THE HYPERCUBE SYSTEM

A. Introduction

This chapter draws on the field test results presented in the preceding chapters to make recommendations for improvement, dissemination, and institutionalization of the hypercube system. These recommendations are predicated on the research team's overriding conclusion that the hypercube queuing model is a useful and suitably reliable field operations planning tool which can be successfully employed by police planners to analyze and improve field operations. Not all police departments can benefit from hypercube, but procedures for identifying those which can have been identified, and the resulting "market" for the system appears large enough to suggest a potentially promising future for hypercube.

On the other hand, a number of problems have been uncovered which, if uncorrected, will greatly diminish hypercube's prospects and the potential benefits which can arise from its use. The very attractive features of the interactive hypercube software will almost certainly be available to few police departments due to its relatively high data processing costs. The version of the software which most users could employ, written in COBOL and operated in batch mode, lacks many of the desirable features of advanced PL/I versions, and requires a rigid input format not nearly as easily understood as that of the interactive program. Even the PL/I versions lack the ability to model certain aspects of field operations seen as essential by police users, although the methodology for including these features has been developed by Dr. Larson and his associates. Also, another powerful software package, PCAM, complements hypercube so well in most situations that the two should be used together. PCAM, however, lacks validation and training materials comparable to those now available for hypercube.

Although an improved COBOL version of the hypercube software will greatly expand the number of law enforcement agencies which can utilize hypercube on their own data processing equipment, the majority of the agencies in the United States still do not have access to such equipment. Many of the agencies without computers will find use of hypercube on a commercial time-share system also infeasible because of its cost, even when preliminary estimates indicate that hypercube could improve service levels. For these agencies, a completely manual planning system derived from hypercube should be developed. While such a system would necessarily be limited in its capabilities, it appears that many of the concepts of police resource allocation derived from the hypercube model (e.g., the burden of central location) could be utilized in a manual planning computational procedure. This type of manual field operations planning aid would be an ideal training resource for in-service management training programs.

This project has drawn up a blueprint for technology transfer for hypercube, and has begun to put it into operation. Its elements are described in this chapter. If the proposed activities can be carried out, the number of police agencies which can use and benefit from hypercube will be significantly increased.

If not, hypercube will probably be used by only a small number of larger police departments and, unless championed by private firms or government agencies, will fall into eventual disuse.

B. Information Dissemination

An informal canvas of 100 police planners and executives attending training programs at the Traffic Institute during 1976 revealed that only a handful had ever heard of hypercube. This finding was just one of many during the field test project which indicated that a considerable effort will be required to increase the law enforcement community's awareness of hypercube. The following are recommended to assist in accomplishing this objective.

Solicit the Cooperation of Influential Organizations and Services

1. Technology transfer programs

TIPPA staff has made initial contacts and supplied preliminary field test information to the technology transfer programs discussed earlier (see Table 6-1 for a recap). Experience indicates that unless there is active follow-up of such contacts the likelihood of continued interest will diminish considerably.

2. Professional associations and organizations

Similar follow-up contacts are suggested for the professional associations and organizations identified in Chapter V (see Table 6-2 for a composite list).

3. Criminal justice planning agencies

Results of the field test program and information about the availability of field test products should be communicated to LEAA

Table 6-1

TECHNOLOGY TRANSFER PROGRAMS FOR FOLLOW-UP CONTACTS

National Center for Criminal Justice Planning and Architecture
National Clearinghouse for Criminal Justice Information Systems
National Governors Conference
National Conference of State Legislatures
National Conference of State Criminal Justice Planning Administrators
Division of Technology Transfer, LEAA
National Referral Center, Library of Congress
Public Technology, Inc.
International City Management Association (innovations evaluation and dissemination program)
Federal government programs listed in "Directory of Federal Technology Transfer"
State and local technology transfer programs
Office of Policy Development and Research, HUD

Table 6-2

PROFESSIONAL ASSOCIATIONS FOR FOLLOW-UP CONTACTS

International Association of Chiefs of Police
International Conference of Police Associations
Association of Police Planning and Research Officers
State and regional police chiefs' associations
State and regional police officers' associations
Urban Regional Information Systems Association
Police Foundation

local, state, regional, and national offices and to specific LEAA programs concerned with police resource allocation or training.

4. Software dissemination programs (see section below)

5. Technical assistance programs (see section below)

6. Training programs (see section below)

Publish Announcements, Articles, and Reports on Hypercube and Field Test Results

1. National Technical Information Service (NTIS)

Reports produced during the field test should be submitted to NTIS for inclusion in its library and announcement in its publications Urban Technology and Problem Solving Methods for State and Local Governments.

2. National Criminal Justice Reference Service (NCJRS)

A request should be submitted to NCJRS for announcement of the availability of the field test reports in its Selective Notification of Information. Another announcement should be made regarding the interactive hypercube software.

3. Law enforcement newspapers and magazines

Brief press releases which summarize the field test results, potential benefits of hypercube use, and how to obtain reports and software, should be issued to these publications. Releases should be sent to editors of bulletins published by state police chiefs' and police officers' associations, and of publications of national scope, such as Crime Control Digest, Law Enforcement News, Criminal Justice Newsletter, Police Chief, The Law Officer, etc.

4. Public administration newspapers and magazines

Press releases should also be sent to state associations of public administrators, and to the publications of national associations such as ICMA (TARGET, Nuts and Bolts, Public Management) and the National League of Cities (Nation's Cities). If available, the Mathematica, Inc. article on hypercube should be submitted to one of the national magazines.

5. IACP equipment directory

An updated description of the hypercube software and how to obtain it should be submitted to this publication each time it is reissued.

Exhibit Hypercube at Professional Association Meetings

An excellent way to create interest in hypercube among law enforcement professionals and public officials is to operate an exhibit booth on hypercube at meetings of professional associations. National meetings of IACP and ICMA attract thousands of participants. State and regional associations attract hundreds (e.g., the Association of Police Planning and Research Officers). The exhibit booth designed for the RANN 2 Symposium is ideal for this type of use, and is available from TIPPA. It measures about 30 x 10 feet, and includes enlarged photographs, graphics, and a continuous loop film on the field test project.

The main drawback to exhibiting in this manner is its cost. Expenses are likely to include:

- salaries, travel, and subsistence for exhibit personnel,
- booth rental ($100-600),
- shipping expenses for exhibit,
- rental of portable teletypewriter equipment, and
- data processing costs for demonstrations.

If a market for technical assistance services involving hypercube can be created, it is possible that some consulting firms might bear these expenses in connection with promoting new business. Initially, however, NSF or other government technology transfer funds will be required.

Additional Development Work Required to Facilitate Information Dissemination

1. Improved COBOL program

As described below in the section on software, development of an improved COBOL program is recommended. If developed, an effort should be undertaken to disseminate information on its availability and benefits.

2. ICMA innovations project

This project could be very effective in communicating the potential benefits of hypercube to city management personnel. For each innovation evaluated, a users committee is established and results of field tests or other evaluations are carefully reviewed. Considering the scope of the hypercube field test and the amount of information generated, some TIPPA assistance to the ICMA committee may be required. Should the committee subsequently endorse hypercube, it would distribute a technology transfer packet on it to ICMA's 5,000 members.

3. Centralized information dissemination program

During the field test project TIPPA has served as a coordinator of information dissemination for hypercube, as outlined in the previous chapter. This work has resulted in a steady stream of inquiries about hypercube which is expected to continue for some time. Provision should be made for adequate response to these inquiries, either by TIPPA or some other organization.

Additionally, the dissemination program recommended in this chapter should be centrally coordinated until hypercube is suitably established in the institutions recommended for software dissemination, technical assistance, and training.

4. Improved PL/I programs

Also outlined in the section on software below is a recommendation for incorporating additional modeling capabilities in the PL/I programs. Such changes should be adequately documented by updating appropriate reports, and should be suitably announced.

C. Software

Software recommendations relate to needed improvements to the computer programs, dissemination efforts, and supportive services.

Recommended Changes to the Hypercube Software to Facilitate Dissemination

1. Programs should be modified to account for travel barriers, priorities, and non-cfs work.

An appropriate organization should be funded by NSF to make these modifications to both interactive and non-interactive versions of the software.

2. A manual input process should be substituted for the interactive monitor.

Figure 6-1 shows samples of the two input files required by the hypercube software. Both files can be easily constructed with the interactive system, but users of non-interactive systems must construct them unassisted except for a user's manual not easily used by persons unfamiliar with computers. Difficulties include (1) rigid requirements for locating data items within prespecified card fields, (2) use of data identificaion codes and

```
M =  3     R = 16     NUM = 1     ESTSTAT = 1     ;
'GLOSSARY'
P_DIST = 'ZONE      '
ATOM = 'RPT BLOC'
P_UNIT = 'ZONE CAR          '
CFS = 'INCIDENTS          '
NM_UNIT(  1) = 'ZONE CAR'
NM_UNIT(  2) = 'ZONE CAR'
NM_UNIT(  3) = 'ZONE CAR'
NM_DIST(  1) = 'ZONE     '
NM_DIST(  2) = 'ZONE     '
NM_DIST(  3) = 'ZONE     '
NO_UNIT(  1) =      1
NO_DIST(  1) =      1
NO_UNIT(  2) =      2
NO_DIST(  2) =      2
NO_UNIT(  3) =      3
NO_DIST(  3) =      3;
 TITLE'    'SAMPLE ANALYSIS OF A DISTRICT PLAN
 PRNT_SP_ALC'
 PRNT_CFS'
 PRNT_VST'
'PRNT_PATROL'
 PRNT_TT'
 PRNT_COST'
 PRNT_TR'
'TOTLNO'
 AM'
'1'        1       5     121     131     141     151     161
'2'        2       5      71      81      91     101     111
'3'        3       5      11      21      31      41      51      61
 D_SCALE'    1.000
'SPEED'     20.00
 PATROL' .        10.0
'TX'
 CORTM'      0.300

'ICM'
'FRST'
'SERVTM'       22.0

'RUN'   6.00    0.00 .
```

Figure 6-1

SAMPLE INPUT FILE FOR
THE HYPERCUBE PROGRAM

alphabetic variables which involve abbreviations and algebraic notation not understood by non-mathmaticians, and (3) no automatic error checking.

Examination of the interactive monitor program reveals that it performs the following functions:

- steps the user through the process of specifying the input items required;
- lists the alternatives available at each step and provides more detailed, tutorial explanations if necessary;
- solicits numbers or names required for each step;
- performs limited error checking and notifies the user of errors identified; and
- produces the card image formats required in the input files, by providing card identification codes, variable names, proper location of data within the input "cards," and proper sequencing of input cards in the files.

It is recommended that an experimental "programmed instruction" handbook be developed to guide program users in the preparation of input files. Such a handbook, it is believed, could embody almost all the capabilities of the interactive monitor, and thereby provide the non-interactive program user with the same benefits as the monitor user. The final product resulting from use of the input handbook would be a set of coded forms ready for keypunching. The resulting cards would form either a complete input deck or modifications to a previously produced deck. Input formatting with the handbook would completely eliminate computer costs associated with the monitor, allow many police departments whose computers do not support software written in the PL/I language to use hypercube on their own computers, and provide a cheaper, simple alternative to dissemination of the monitor software. If successful, the experimental handbook could serve as a model for input formatting guides for numerous public service resource allocation programs now in existence.

Once developed, the handbook should be field tested and revised before final dissemination. Field test police departments like San Diego, Fresno, and San Jose would be ideal sites for testing the handbook since they plan to implement the COBOL hypercube program and are familiar with the interactive monitor.

3. Improved COBOL program

Since the COBOL hypercube software is virtually the only version which police departments can run on their own computers, this program should be modified as follows:

- incorporate features available in PL/I versions which are not now available in the COBOL version;
- reduce core storage requirements;
- make the program more compatible with PCAM (see item 4 below); and
- make the program compatible with the programmed instruction guide described above and with the additional capabilities of the interactive software.

Once modified, the program should be field-tested before final dissemination.

4. Creation of a PCAM-Hypercube package

The field test finding that police departments can cut the cost and time required for hypercube analyses by also employing PCAM, suggests that a PCAM-hypercube software package be created. PCAM's benefits include a more global perspective than hypercube (i.e., all watches and patrol regions can be considered simultaneously), prescriptive capabilities regarding optimal car allocations, and explicit modeling of call priorities and non-cfs work. Development of the PCAM-hypercube package would involve:

- redesign of input formats to allow both programs to access the same data file so that common elements are input only once;
- limited validation to verify the accuracy of PCAM--this could be readily accomplished with the data collected by TIPPA for the hypercube field test;
- development of a programmed instruction handbook for formatting PCAM input, or expansion of the hypercube handbook to include additional items required for PCAM;
- preparation of a COBOL version of the PCAM software which is currently written in FORTRAN; and
- limited field testing of the package before dissemination.

5. Study the feasibility of adapting hypercube to be compatible with the USAC law enforcement module

The USAC law enforcement module provides basic data management services for departments utilizing it. It is designed for use by agencies which are upgrading from manual to computerized record keeping, and incorporates record formats and data collection forms to facilitate input to the system. It is one of the few standard police data management packages available and was designed for ease of implementation. It is likely to be used by many more police departments in the future. A study should be made to determine whether hypercube input data can be derived from the USAC module, and, if so, a USAC-compatible version of hypercube should be developed.

6. Feasibility study of a completely manual planning tool based on the hypercube model

As explained in the introduction to this chapter, improvement of the hypercube software will only enhance its availability to police agencies having access to adequate computer facilities, either in-house or time-shared. However, this will still leave the majority of the nation's police departments effectively without access to hypercube because of the large number lacking access to and experience with computers. For this reason, it is recommended that a study be undertaken to determine the feasibility of a completely manual planning tool based on the hypercube model. Such a tool would be based on the principles of police patrol allocation derived from hypercube and other allocation models. It could, with a reasonable amount of effort, aid a police planner in assessing and improving field operations. While it would not reproduce the detail and accuracy of the hypercube software, it could probably yield most of the important insights at a fraction of the cost. Documented in a handbook or workbook, it would be an ideal training aid.

A very preliminary examination of the feasibility of this type of tool suggests that it could be based on the following:

- queuing curves relating number of patrol units, workload, and response delay (these would be derived from runs of the hypercube and PCAM software);
- rules for approximating the level of cross-district dispatching as a function of the number of patrol units and workload;
- a procedure employing the "burden of central location" concept for estimation of the workloads of individual patrol units;
- the so-called "square root law" for approximating average travel time as a function of area patrolled and average car availability;

- formulas for estimating the volume of non-called-for-service work as a function of the called-for-service workload;
- development of a set of tabulated, standardized hypercube printouts for appropriate sets of input parameters among which a planner would be likely to find one reasonably similar to his own field operations parameters; and
- direct adaptation of some of the computational procedures used in the hypercube and PCAM algorithms.

The feasibility study should include preparation of a draft of the workbook and a field test of its use by police planners.

Inclusion of Hypercube in Software Libraries and Dissemination Programs

The field test project identified the software libraries and dissemination programs listed in Table 6-3 as appropriate for future distribution of the hypercube software. Inclusion of hypercube in these libraries and programs should be possible at little or no cost. Because each dissemination source would automatically include hypercube in its regular information dissemination programs (e.g., catalogs, newsletters, annual meetings, etc.), it seems worthwhile to include hypercube in as many as possible. Although it will not take a great deal of effort to follow through on the initial contacts made by TIPPA regarding hypercube, it will require enough to warrant specific provision for this project. This is an important final step in the dissemination of hypercube which should not be left to chance. Responsibility for following through should be assigned to a single organization which can, at the same time, help coordinate the dissemination activities of those sources which agree to take hypercube into their program libraries. The organization can also be responsible for

Table 6-3

SOFTWARE LIBRARIES AND DISSEMINATION PROGRAMS FOR FOLLOW-UP CONTACTS

National Clearinghouse for Criminal Justice Information Systems
Center for Advanced Computation
Computer Software Management and Information Center (COSMIC)
NTIS Computer Products Division
National CSS, Inc.
Massachusetts Institute of Technology - Hypercube Research Project
Public Technology, Inc. Software Library
Urban Information Systems Interagency Committee (USAC)
Regional criminal justice information systems
TIPPA
Private management consulting firms

periodically updating the entry on hypercube in the IACP equipment directory and other catalogs not tied directly to a software distribution program.

Program of Technical Assistance to Support the Hypercube Software

Because hypercube is a complex software package designed for use in a specialized area of law enforcement planning, and is documented in a number of very technical reports, many software dissemination programs will be reluctant to include hypercube without an arrangement for needed technical assistance. Creation of the necessary expertise within the staff of a dissemination program can be costly and unproductive unless the demand for the software package is great. Consequently, such organizations often prefer to act as brokers between users and technical assistance sources, limiting their own services to the distribution of copies of the computer programs and related documentation.

D. Technical Assistance

Technical assistance requested of TIPPA by the field test police departments mainly concerned data collection prior to the training workshop, and telephone consultations on use of the software after the workshop. A great deal of technical assistance was given at the workshop itself, especially in connection with the solution of the sample district design exercises. Because any student's difficulty could be resolved and explained to the rest of the class by the workshop staff, the participating police planners were usually able to cope with similar problems without additional assistance.

The field test experience, and evidence compiled in the survey of hypercube program owners, suggests that, while police users of hypercube do not require a great deal of technical assistance, its availability is essential to the success of the exercise. Without the training and assistance that TIPPA provided, it is doubtful that any of the field test participants would have even approached the levels of accomplishment actually achieved.

The following recommendations deal with assuring the future availability of technical assistance and with changes in the hypercube system which should further reduce users' needs for such assistance.

Development of Sources of Technical Assistance for Hypercube Users

1. Software dissemination programs

The most likely sources of hypercube expertise will be software dissemination programs. Programs which cannot themselves provide this type of assistance will probably refer user inquiries to another source. A previous section of this chapter identified the organizations which appear best suited for dissemination of the hypercube software and provision of technical assistance. A follow-up program should be implemented to carry on the initial efforts of the field test project to install hypercube in these organizations, and to assist them in developing the necessary expertise.

2. LEAA-funded technical assistance programs

Most law enforcement agencies have limited funds for purchasing technical assistance services, and are very reluctant to use outside consultants. Since the early 1970's, LEAA has funded a number of technical assistance programs which offer free services in certain areas. As described in the previous chapter, these programs are promising candidates for provision of technical assistance services to hypercube users, or for providing referral services. A follow-up program should be implemented to assist these programs in developing expertise in hypercube. The organizations are:

National Center for Criminal Justice Planning and Architecture

Westinghouse Corporation

Public Administration Service

Science Advisor Program (Office of Technology Transfer)

3. Public technology transfer organizations

A follow-up program should also be implemented for the technology transfer organizations previously identified:

Public Technology, Inc. (non-NASA programs)

NASA's technology applications teams, Stanford Research Institute and PTI

California Innovation Group

New England Innovation Group

Other state, regional, and local transfer programs

4. Private industry and police service organizations

Private firms and police service organizations which provide management consulting services to police departments should be encouraged to utilize hypercube and offer technical assistance to client departments. A follow-up program should be instituted to apprise such organizations of the results of the field test project and of the newly developed software and documentation. Such organizations identified during the field test include:

Urban Sciences, Inc.

Public Systems Evaluation, Inc.

Public Management Services, Inc.

IACP's police management and operations division

Public Administration Service

5. The Institute for Public Program Analysis

TIPPA is committed to continuation of its hypercube technical assistance services.

Recommended Modifications to the Hypercube System Which Will Reduce User's Needs for Technical Assistance

The previous discussions have identified the following modifications of the hypercube system which will reduce user's needs for technical assistance:

- development of a programmed instruction guide to formatting input as a substitute for the interactive monitor for users of non-interactive versions of the software;

- development of a PCAM-hypercube software package to reduce the cost and time required for hypercube analyses;
- experimentation with field operations design workshops as a way of cutting technical assistance costs by sharing them among a number of police agencies;
- modification of the software to account for travel barriers, priorities and non-cfs work;
- development of an improved version of the COBOL software by incorporating features presently limited to PL/I versions; and
- adaptation of hypercube for compatibility with the USAC law enforcement module.

The value of these modifications cannot be overemphasized. Each can contribute significantly to the ability of future users to understand and use the hypercube software, and thereby reduce the need for outside assistance and the cost of whatever assistance is still required.

Information Dissemination Regarding Technical Assistance

Available technical assistance resources will be of no value if potential users do not know of their availability. The companion report, "How to Set Up Shop for Use of the Hypercube System," includes a section on obtaining technical assistance. Technical assistance sources should also be registered with organizations such as the National Referral Service and the Kansas state law enforcement planning agency, which publish catalogs of technical assistance resources.

It is also recommended that a training program be presented for representatives of organizations committed to providing technical assistance to hypercube users.

E. Training

Police planners who participated in the field test training seminar and later utilized hypercube indicated that the training was extremely helpful, and that without it most of them probably would have given up on hypercube. TIPPA's survey of agencies presently having a copy of the hypercube software also failed to identify a single instance in which hypercube was successfully used without the involvement of a consulting firm. When consultants were involved, they generally operated the software themselves to avoid the effort involved in training agency planners to do it. At least one program owner postponed using hypercube until he could attend a training program. These findings suggest that the availability of hypercube training in the future will be a critical factor in hypercube utilization by the law enforcement community. The following recommendations deal with the provision and development of this type of training.

Encourage Inclusion of Hypercube Training in Appropriate Criminal Justice Training Programs

1. Training programs identified during the field test

Initial contacts were made with representatives of numerous criminal justice training programs during the field test, as described in the previous chapter. A follow-up program should be undertaken to supply these training programs with the final products of the field test and to assist those interested in including hypercube in training. Follow-up should include:

University-based programs

Conference-based programs (e.g., national meetings)

Special-purpose LEAA programs (especially those of national scope)

2. <u>Identification of additional training programs</u>

Additional training programs should be identified by review of the "Criminal Justice Education and Training Directory" and of law enforcement publications. Information on hypercube training should be sent to those identified as potential users.

3. <u>Software dissemination programs which can include training</u>

The software dissemination programs identified in the field test which can include training (e.g., Center for Advanced Computation, Center for Criminal Justice Information and Statistics, and M. I. T.'s Urban Systems Analysis course) represent promising sources of hypercube training since they already have or are likely to develop expertise in hypercube in order to support the software. Because they may also offer technical assistance, a follow-up effort should be made to encourage and assist these programs in adopting hypercube.

4. <u>TIPPA hypercube seminar</u>

An effort should be made to assure the presentation of the TIPPA seminar at regular intervals, either by TIPPA or another appropriate organization. The frequency of presentation should be adjusted to keep the classes large enough to cover expenses. This seminar is also ideal for training persons involved in hypercube dissemination programs themselves (i.e., information dissemination, software dissemination, technical assistance, and training) and should be used initially to aid in the initiation of these services.

5. <u>Facilitate funding and approval of hypercube training</u>

Additional effort should be directed towards training course approval and funding activities of state law enforcement planning agencies and Police Officer Standards and Training (POST) commissions. Without this type of support, wide-scale participation by law enforcement personnel in hypercube training will be severely, if not fatally, handicapped.

6. Publish articles on the hypercube training materials

Newsletters such as Training Aids Digest reach hundreds of law enforcement training administrators and thousands of police officers seeking useful in-service training. Articles describing the benefits of hypercube and the availability of the hypercube training materials should be submitted to a number of these publications.

7. LEAA's Office of Criminal Justice Education and Training (OCJET)

The announcement of hypercube and related training materials by the director of OCJET to all LEAA regional offices will continue to generate inquiries from these agencies for some time. Resources should be available to respond to these inquiries, including some staff assistance for planning state or regional training conferences (e.g., such as proposed to TIPPA by the Denver regional office). Major expenses should be borne by LEAA, but initial response efforts will not be easily supported by that agency.

Development of Additional Training Resources

1. Use of the COBOL program

Previous recommendations have suggested improvement of the input formatting procedures and of the modeling capabilities of the COBOL program. If these are carried out, the training handbook should be revised accordingly. This should be a high priority task, since the improved COBOL software will be the only hypercube system most police departments can operate on their own computers. Also, use of the revised handbook in training programs will cut the cost of training because use of the interactive monitor can be dropped.

2. Training materials for PCAM

If the recommended PCAM-hypercube software package is developed, it will be essential to include information on the PCAM component in the training handbook.

3. Continuing evolution of the hypercube software

Resources should be provided for updating the training handbook as additional capabilities are incorporated in the hypercube software. For example, incorporation of travel barriers, non-cfs work, and call priorities into the model should be documented for the handbook.

4. Field testing new training materials

Before dissemination, new training materials should be reviewed by police planners familiar with hypercube, then revised, based on their feedback. Planners from San Diego, Fresno, and San Jose who participated in the present project are suggested.

APPENDIX A

THREE CASE STUDIES OF HYPERCUBE IMPLEMENTATION

This section details the experience of the three police departments which participated in the field testing of the hypercube programs and subsequently completed the implementation of hypercube-designed patrol beats: Burbank, Fresno, and St. Louis County. These three accounts provide an overview of the types of situations in which hypercube is likely to be used and potential difficulties which hypercube users are likely to encounter.

Each study is an attempt to convey the most salient features of hypercube use in the respective departments. The activities and events which comprised the field test program are discussed in Chapter II, and are mentioned only briefly in the following narratives. Likewise, routine procedures involved in hypercube use and model-specific problems which are likely to be faced by most users are not discussed in detail.

Each case study emphasizes a different aspect of hypercube use. In Burbank, a great deal of effort had to be devoted to the collection of input data. In Fresno, hypercube was used to help justify a shift in manpower allocation from a static (24-hour) beat plan to one using five different beat plans at various times of the day. The St. Louis County experience illustrates implementation pitfalls involved and ways in which these can be overcome. Following each narrative, brief conclusions are drawn regarding the use of hypercube in other departments.

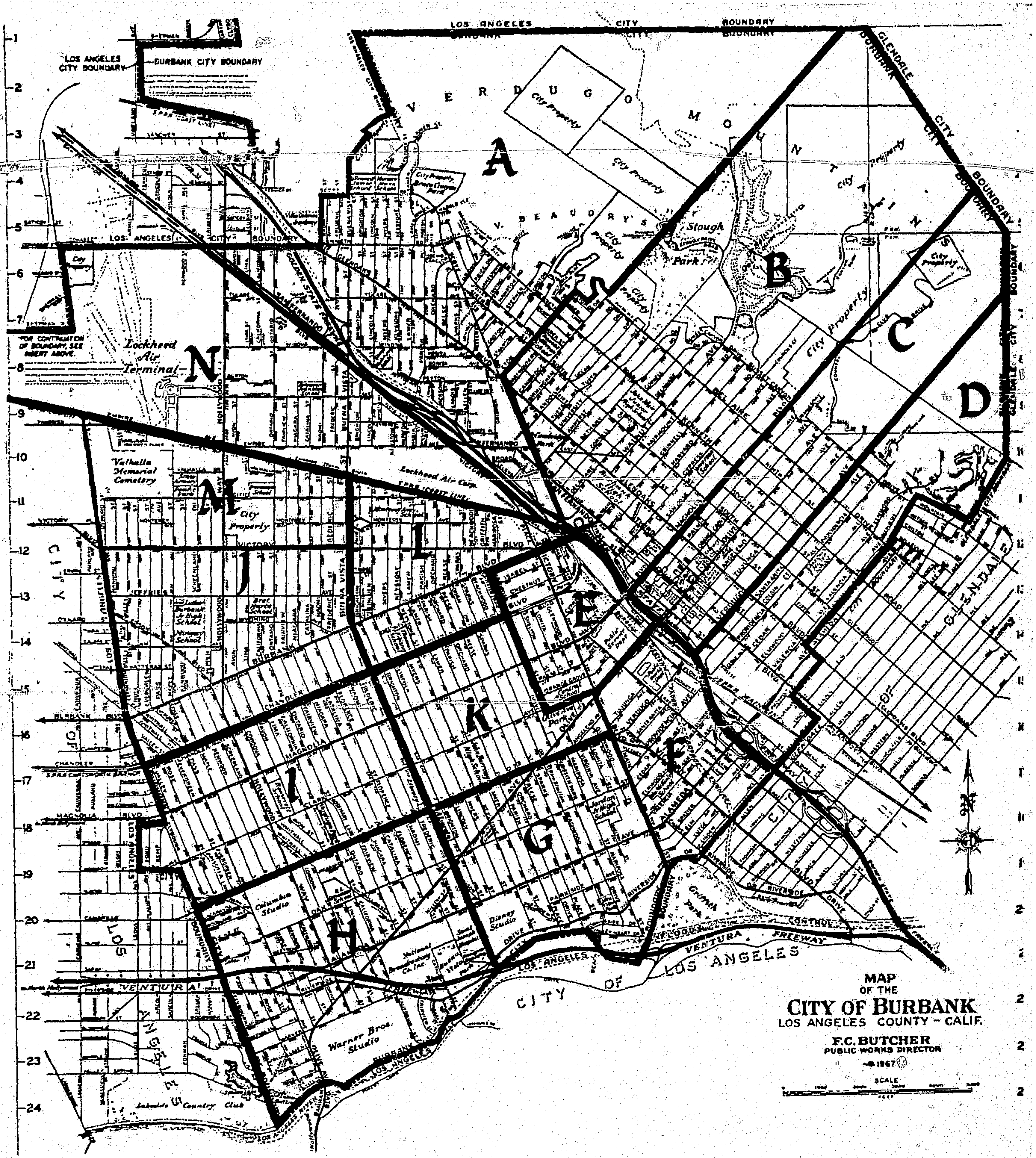
A. <u>Burbank, California</u>

<u>Background</u>

The City of Burbank is located in Los Angeles County in the northern portion of the Los Angeles metropolitan area. It adjoins the City of Los Angeles along its northern, western, and southern boundaries, and the City of Glendale on the east. The city has a population of approximately 85,000 and has a total area of 17.1 square miles. Located within the city are several major television and motion picture studios, the Hollywood-Burbank Air Terminal, and numerous manufacturing and commercial establishments. The Golden State Freeway divides the city from northwest to southeast, and the northeast portion of the city contains a sparsely populated region currently experiencing some upper-income residential development.

Crime patterns have remained stable in Burbank for many years, with the exception of increased property crime in one region. As a result, the same beat plan had been used since 1961 when a new police building and communications center was completed. This plan divided the city into two command sectors, with five beats in Sector 1 and nine beats in Sector 2. These same beats were used around the clock. During each watch, a sergeant was in command of patrol operations in each sector. This beat plan is shown in Figure A-1.

Although the 1961 beat plan was designed for 14 patrol units, the actual numbers of units in service each watch varied considerably. Each sector sergeant used his discretion to combine beats when manpower shortages occurred. When more than 14 units were fielded, the extra manpower was used as back-up sectorwide or to provide double coverage in busy beats. During 1975, manning normally consisted of 10 to 12 units on the day shift (8:00 a.m. to 4:00 p.m.), 12 or 13 units on both the swing shift (4:00 p.m.



*Sector 1 contained beats A, B, C, D, and N, while Sector 2 contained beats E, F, G, H, I, J, K, L, and M.

Figure A-1

OLD BEAT PLAN USED BY THE
BURBANK POLICE DEPARTMENT*

to midnight) and graveyard shift (midnight to 8:00 a.m.), and four units on the overlay shift (7:00 p.m. to 3:00 a.m.). Thus, scheduled patrol strength varied regularly from 10 to 17 units. When a four-day work week with 10-hour shifts was initiated in the fall of 1975, additional variation in patrol strength resulted during periods of shift overlap. Absences at times reduced patrol strength to six units.

Participation in Project

From the time the Burbank Police Department was approached about the field test project, there was interest in participating. A need existed to bring the beat plan more in line with current patrol strength, even though the amount and type of crime had not changed significantly. Storage of police data on the city's computer was being considered, and it was felt that the beat structure and data collection procedures should be examined before computerized record-keeping was initiated. Also, it was felt that department personnel could gain valuable expertise through the training involved in the project.

Data collection, however, presented a major obstacle, and there was considerable doubt about whether the data could be gathered at a reasonable cost within the time available. The department had no computerized data and no established system of geographical reporting areas. Before using the hypercube programs, the department had to design a reporting area system for the city and construct a data base by sampling dispatch tickets and officers' daily activity logs. There was considerable concern that the project would require more involvement by command and supervisory personnel than could be justified in terms of potential benefits to the department. However, the level of effort required by the project seemed much more reasonable when it was found that department administrative aides could complete much of the data collection and TIPPA could provide data processing assistance.

Members of the research team met with department personnel who were to be involved in the project to finalize data collection plans. Subsequently, administrative aides in the department devised a reporting area system and collected sample data from dispatch tickets, assigning incident addresses to appropriate reporting areas. The research team had the data keypunched and processed as needed for input to the hypercube programs.

Collection of Input Data

The first task facing the department in obtaining input data was the creation of a reporting area system for the city. Following guidelines suggested by the research team, the department staff used a large city map to design an initial set of reporting areas. This effort resulted in the creation of 45 reporting areas. Additional reporting areas were subsequently added by subdividing the initial ones, following a meeting between department staff and members of the research team. The resulting set of 102 reporting areas included 50 in Sector 1 and 52 in Sector 2.

The guidelines distributed by the research team suggested that reporting areas be compact, uniformly sized, encompass areas of homogeneous crime patterns, and have boundaries which did not cut across major thoroughfares or natural boundaries. The resulting system of reporting areas followed these guidelines, and at the same time avoided cutting census tract boundaries and current beat boundaries. Major studios and similar establishments were kept within single reporting areas. Once the reporting areas were drawn, the center coordinates were plotted and their areas computed.

Historical incident data needed for input to the hypercube programs included the relative workload in each reporting area, the arrival rate of dispatched and self-initiated calls for service, and the average service time for all calls for service. None of these items were routinely collected by the Burbank Police Department, necessitating the construction of this data base by examining department records. The documents used included the following: the "complaint record," which is completed on all calls for service received by a dispatcher; the "officer's daily log," which lists each officer's activities during a watch; and the "officer's patrol record," which lists the amount of time spent by each officer for self-initiated activities, report-writing, etc. Samples of these documents are shown in Figures A-2, A-3, and A-4.

Call for service data were gathered from complaint records. Approximately 30,000 of these records are completed each year and filed by date and time. A random sample was obtained by pulling every twentieth record from the files for the period from May 1, 1975, through April 30, 1976. This yielded a sample of about 1745 calls for service. For each incident, information was collected on the date and time of the incident, the type and identity of the units dispatched, the incident location, and various times stamped on the card. Reporting area numbers were assigned to each incident, based on the address shown on the card and the newly-drawn reporting

COMPLAINT RECORD 76-13609

UNITS ASSIGNED	REC'D BY:
	D.R. NO: 4771
	ARREST NO:
INFORMANT:	VEH LIC: YR:
ADDRESS:	COLOR:
PHONE:	MAKE: MODEL:
NATURE OF COMPLAINT:	VIN:
LOCATION:	1028(REG. OWNER) NAME:
VICTIM:	ADDRESS:
ADDRESS:	
PHONE:	
LOST PERSON OR SUSPECT:	DISPOSITION OF COMPLAINT:
ADDRESS:	
ALIAS: OP. LIC:	
D.O.B.	
SEX RACE HGT WGT EYES HAIR AGE	
CLOTHING:	
OTHER DESCR:	REPORTED TO: DEPT:
ML 728 REV. 10-73	DATE:
	TIME:

TIME COMPLAINT RECEIVED	TIME UNIT DISPATCHED	TIME AMBULANCE DISPATCHED	INHALATOR OR OTHER DISPATCHED
MAY 1 ... 76			
INHALATOR OR OTHER ARRIVED	TIME AMBULANCE ARRIVED	TIME UNIT ARRIVED	TIME COMPLAINT COMPLETED
		MAY 1 ... 76	6 36 AM '76

Figure A-2

SAMPLE COMPLAINT RECORD USED BY THE BURBANK POLICE DEPARTMENT

PAGE: 1	DAY: THUR	DATE: 7-24-75	WATCH: I 11-7 (graveyard)	DETAIL TIME: 6 1/4 HRS.	HAZ.	EQUIP.	PARK.	F.I.
BURBANK POLICE DEPARTMENT OFFICER'S DAILY LOG			AREA 7/1 [illegible]	CAR #21	—	1	—	[illegible]
OFFICERS:				IN 790 OUT 740	OBS. FEL:	—	MISD:	
				TOTAL:	DET. FEL:	—	MISD:	

ITEM NO	TIME REC'D	TIME ENDED	SOURCE	LOCATION	CLASSIFICATION	NAMES, ADDRESSES, DISPOSITION, REMARKS, ETC.	DR#, A# OR CITATION #
1	11:55	12:05	[illegible]	[illegible]	[illegible]		
2	12:05	12:25	OBS	[illegible]	[illegible]		
3	12:25	12:55	D/O	[illegible]	415 [illegible]		
4	12:55	12:55	OBS	[illegible]	MISC		
5	1:05	1:15	D/O	[illegible] / [illegible]	[illegible]		
6	1:15	1:25	OBS	[illegible]	[illegible]		
7	1:25	2:00	OBS	[illegible]	[illegible]		
8	2:10	2:30	D/O	[illegible] / HWAY	415 F[illegible]		[illegible]
9	2:30						
10	[illegible]						

Figure A-3

SAMPLE OFFICER'S DAILY LOG USED BY THE BURBANK POLICE DEPARTMENT

OFFICER ______ DAYS OFF ______

OFFICER ______ DAYS OFF ______

WATCH III SGT (20) ______ SGT (21) ______

LT. ______ SGT (RELIEF) ______ SGT (RELIEF) ______

BURBANK POLICE DEPARTMENT
OFFICERS PATROL RECORD

MONTH February 19__

HAZ CIT AVG 2.41

FI CARD AVG 1.60

DAY OF MONTH	DETAIL TIME SPECIAL ASSIGNMENT REMARKS	MISCELLANEOUS: FI AVERAGE	CITATION AVE	HOURS SICK	HOURS IOD	DAYS IN FIELD	MILEAGE	BURG ON BEAT	OBSERVATIONS: TOTAL OBSERVED	OTHER OBS	BURG FOUND	BLDG FOUND OPEN	VEHICLE REC	FI CARDS	CITATIONS: HAZARDOUS	OTHER	PARKING	ARRESTS: ON SIGHT FELONY	ON SIGHT MISD	RESULT OF CALL FELONY	RESULT OF CALL MISD	CODE SECTION AND NUMBER OF PERSONS ARRESTED	REPORTS: HRS RPT WRITING	TRAFFIC ACC	FOLLOW UPS
	Team #1																								
1																									
2		1.20	2.00	24		2½	487		21	8				3	5	2	2		1			3 Days Vac	1		26
3		3.33	3.33			3	640		57	20		1		10	10	4	8		4	1			23	3	
4		1.11	1.56			4½	750		26	8				5	7		4		2				9¾		
5		10.67	8.67	8		1½	795		100	48			2	16	13	2	5	3	11	2	4	2 Days Jail	6¾		1
6																									
7		—	—	24			896		80	4				3	13	1	53	2	4		4	Training Officer	5½	3	1
8		.80	4.00			2½	524		29	6				2	10		5	3	3			School 5 Days	17½	2	2
9				56		14	4092		313	94		1	2	39	58	9	77	8	25	3	8		63¾	8	30
10																						F.I Ave 2.78			
11																						Cit Ave 4.14			
12																						Mile Ave 46.3			
13																									
14																									
15	Team #2				Mil.																				
16					Av.																				
17		.20	.00	39	40.2	5	403		11	9				1			1				1				15
18		.85	2.57	8	40.6	3½	447		29	6		1		3	9	3	4	2	1		1	Jail - 2 Days [illegible]	5½	5	
19		N/A	N/A		41.8	½	996		56	22		1	1	8	9	1	9	1	4		9	Training Off.	19½	5	1
20		.00	.60	24	42.5	5	740		12	6			1		3				2					5	1
21		2.50	1.50		38.8	4	660		78	45½				10	6		6½	2	8		1½	School - 3 Days	10	7	2
22		1.07	2.84		45.0	6½	676		57	4½				7	15½	1		1	5		1	Admin. - 8 Days	5	1	7
23	ng)																								
24	nly)	.22	.11		32.6	4½	147		13	3				1	½		6½		1		2½		6½		
25																							53	23	26
26																									
27																									
28																									
29																									
30																									
31																									
	TOTALS																						116¼	33	56

Figure A-4

SAMPLE OFFICER'S PATROL RECORD USED BY THE BURBANK POLICE DEPARTMENT area map. This information was subsequently recorded on coding forms such as the one shown in Figure A-5.

The dispatch complaint records did not provide a complete picture of total patrol workload for two reasons: self-initiated activity is not shown on these cards, and report-writing time is not necessarily included in the service times stamped on the cards. In computing the relative patrol workload levels for individual reporting areas, it was assumed that self-initiated activity and report-writing would be distributed among the reporting areas in the same proportion as calls for service. Based on this assumption, the call-for-service distribution resulting from the sample of complaint records was used without modification as the distribution of patrol workload among the reporting areas.

To arrive at a reasonable estimate of the average service time for all incidents, it was necessary to obtain a sample of dispatched calls for service and calculate the time required to service each call. These data were obtained by department staff from a sample of daily logs and patrol records. The average service times that resulted from this analysis were 33 minutes for Sector 1 and 29 minutes for Sector 2.

The arrival rate of all calls for service was estimated in the same manner as the average service times. The sample complaint record data yielded an average dispatch rate of 2.078 calls per hour for Sector 1 and 1.626 calls per hour for Sector 2. A separate study by the department staff of dispatch records from January

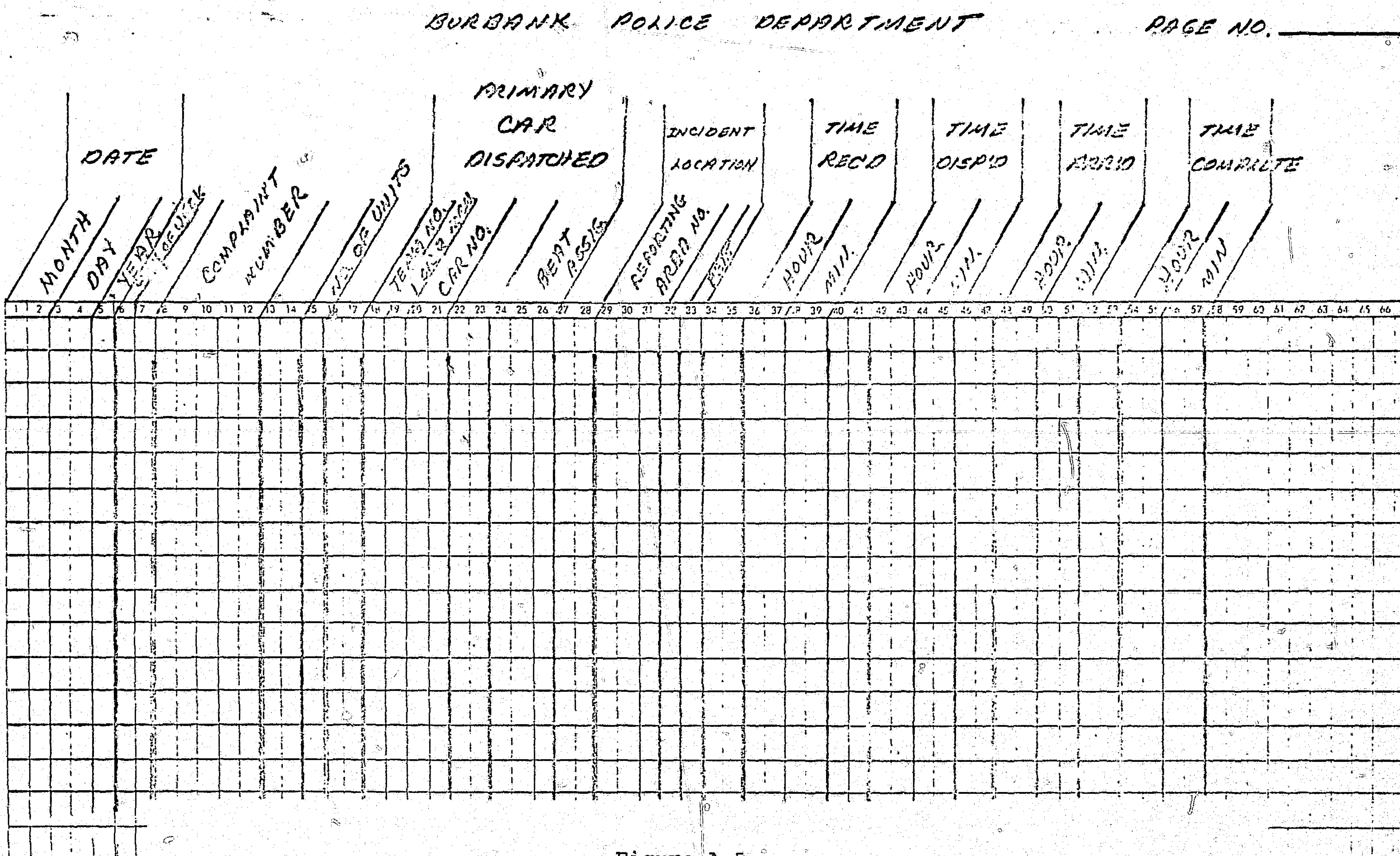


Figure A-5

CODING FORM FOR BURBANK
COMPLAINT RECORD DATA

through March 1976 resulted in estimates of 2.072 calls per hour for Sector 1 and 1.703 calls per hour for Sector 2. These call rates were then adjusted by department staff to account for self-initiated activity, administrative duties, multiple car dispatches, and other out-of-service time. The percentage of time spent on these activities was estimated from the study of daily logs and patrol records.

Use of the Hypercube Programs

Even before the beat design study was begun, there was an awareness in the Burbank Police Department that changes in beat structure were needed. For instance, patrol strength was usually insufficient to allow one car per beat under the 14-beat plan. An earlier patrol workload study undertaken by the department had shown that an average of 10 patrol units were being fielded during the day and swing shifts (8:00 a.m. to 4:00 p.m. and 4:00 p.m. to midnight). Even fewer units were being fielded for the night shift (midnight to 8:00 a.m.). Since a single beat plan for use around the clock was to be produced, the plan was primarily geared to the day and swing shifts. This administrative decision dictated that the new plan would contain 10 beats.

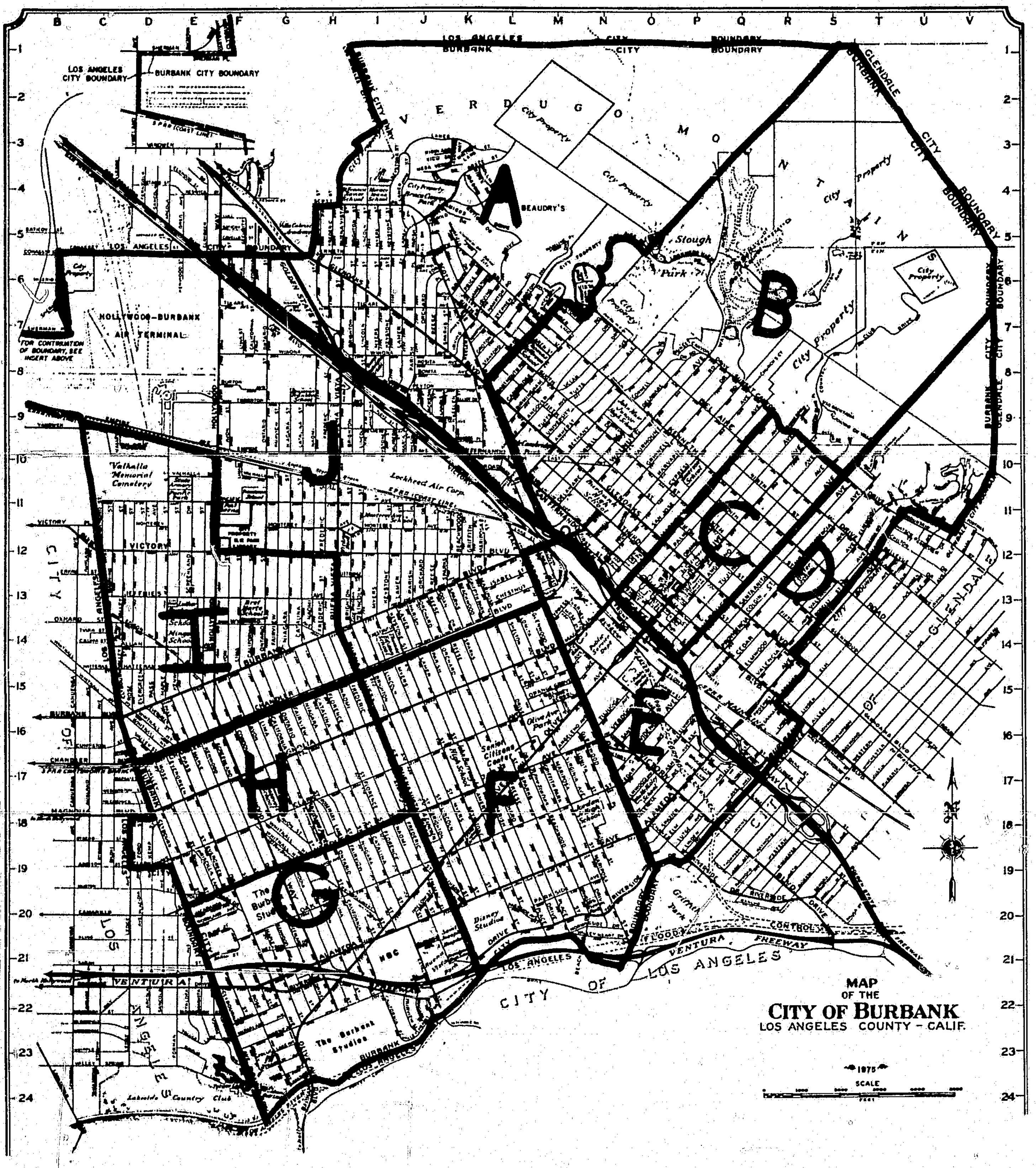
It was also known prior to the hypercube analysis that the citywide workload was not evenly divided between the two sectors. This was confirmed by the sample data collected for the study. A 10 percent difference existed between the workloads in Sectors 1 and 2. Before alternative beat structures were examined, a new sector boundary was established which reduced the workload imbalance to two percent.

Burbank patrol units are rarely dispatched across the sector boundary. On each watch, separate commanders direct the patrol activities in each sector. If a call arrives from a beat adjoining the sector boundary while the beat car is unavailable, another car from the same sector is dispatched if possible. Only in the case of emergency calls or excessive delays are cars dispatched across the sector boundary. Therefore, the sectors were analyzed separately.

Each of the newly-drawn sectors was to be divided into five beats. Based upon hypercube analysis of the 14-beat plan and approximate workload balancing, two alternative plans were drawn for each sector. These initial plans also attempted to encompass distinct neighborhoods within the beat boundaries. Each plan was analyzed using the hypercube programs, with particular attention given to balancing workloads and minimizing cross-beat dispatching. Response time was not of major importance in the analysis, since response times being experienced in the field have been well within acceptable limits and any significant reductions in response times would require additional patrol units.

Based upon the hypercube output for the initial alternatives, no further iterations were deemed necessary. For each sector, one of the original alternatives was recommended for implementation. Additional runs were made, however, to demonstrate which beats could best be combined when less than five patrol units were available in either sector. The new beat plan is shown in Figure A-6.

None of the police staff participating in the study had any prior experience with computers, and for most, it was their first



*Beats A, B, C, D, and E are in Sector 1 and Beats F, G, H, I, and J are in Sector 2.

Figure A-6

NEW BEAT PLAN USED BY THE BURBANK POLICE DEPARTMENT* exposure to the sophisticated analysis of patrol deployment. The training and materials provided as part of the project were sufficient to enable them to complete their analyses. The technical assistance which was provided by telephone following the training workshop was considered essential as a supplement to the formal training.

Application of Hypercube Results

Once the new beat plans had been selected for each sector, they were explained to the field commanders and the department chief. A report was written, outlining the advantages of the new beats. By this time, the patrol commanders and the chief had been acquainted with hypercube and the objectives of the study. There was a willingness to accept the model's performance estimates as reliable, and the new beats were readily approved for implementation.

Future Use of Hypercube

In spite of the good results obtained by the department, continued use of hypercube in Burbank is doubtful. The use of a static beat plan and the stability of the city's population and crime patterns mean that major beat revisions will probably not be necessary in the near future. The reporting area system devised for the hypercube study will probably not be used for on-going data collection by the department. The planner trained in hypercube operation has left the department. Therefore, the amount of effort involved in implementing another hypercube study would be difficult to justify in view of the limited additional benefits of such a study to the department.

Conclusions

Several factors helped make the Burbank experience a positive one:

- Technical assistance from TIPPA, especially during the data collection effort, enabled the department to successfully complete what at first seemed to be an impossible task.
- There was a recognized need to reexamine the existing 14-beat configuration.
- The department was willing to construct the required hypercube data base, using statistical methods not previously attempted.

B. Fresno, California

Background

The City of Fresno is located in the middle of central California's San Joaquin Valley, one of the nation's leading agriculture centers. The city, with its population of 175,000, serves as the business and commercial hub for the entire region. The city is diverse in character, with a thriving downtown business district and enclosed shopping mall, large residential areas, and semi-rural areas near the city limits. The city covers an area of about 54 square miles, and several isolated unincorporated areas are contained within the city limits.

Prior to November 3, 1976, the Fresno Police Department had used the same 16-beat configuration for over 10 years. This plan was used on all shifts and all days of the week. Approximately the same numbers of officers were deployed on each of the three working shifts (7:00 a.m. to 3:00 p.m., 3:00 p.m. to 11:00 p.m., and 11:00 p.m. to 7:00 a.m.), with additional manpower deployed on a "lap" shift (7:00 p.m. to 3:00 a.m.). The units assigned to this lap shift provided back-up assistance for the regular beat cars.

The limitations of this manpower allocation plan had long been recognized. A 1965 study of the department by the International Association of Chiefs of Police recommended changes in the methods of beat design and patrol deployment. In trying to implement the IACP recommendations, however, the department found that its data were not sufficient for the task.

The police department and the city data processing center worked together to improve the department's data collection capabilities. The city was divided into 249 zones with areas of approximately 0.25 square miles, and workload data were captured by hour and by zone. Workload information gathered includes citations, offenses, arrests, court appearances, offense clearances, dispositions, and accidents. The availability of this data has greatly enhanced the department's ability to analyze patrol operations.

Participation in Field Test Project

The Fresno Police Department was first informed of the field test project by the city's CIG science advisor and details of the project were supplied during a visit by members of the TIPPA research team in July 1975. The head of the department's Administrative Services Bureau expressed a definite interest in participating in the project. Hypercube was especially appealing because of its ability to show the inter-relationships between workloads, response times, preventive patrol levels, and interbeat dispatching. The data processing center could provide data on each of these variables, but could not combine them into an integrated analysis of alternative beat designs. The department was also preparing to implement a computer-aided dispatching system (CAD), and wanted a beat design study completed before final CAD implementation. Thus, participation in the field test project coincided with existing department priorities.

Two representatives of the department's Administrative Services Bureau attended the project orientation meeting in May 1976 and the June Training-Design Workshop. With occasional technical assistance from the TIPPA research team, they analyzed existing patrol operations and possible alternatives. A new manpower allocation plan and beat design was approved and implemented in November 1976.

A report has been issued by the department to describe the use of hypercube and the results of its efforts.* The report describes pre-hypercube deployment methods, the analysis of the old 16-beat configuration and the design of new beats for five time periods. Portions of the following sections of this report are based upon that document.

Collection of Input Data

Most of the basic hypercube input data was available through the data processing center, although some additional data had to be collected and other data had to be adjusted to fit the requirements and assumptions of the model. As previously noted, workload data for 1975 was available by zone, but the zone areas and x, y

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*"Beat Design and Manpower Deployment System," Fresno Police Department Administrative Services Bureau (James L. Packard, Deputy Chief), November 1, 1976.

coordinates for the zone centers had to be measured. Actual travel time data were collected by field observation.

Department data indicated that calls for service required an average of 32.05 minutes to complete. Adjustment of this figure was needed to account for administrative time and multiple-car dispatches. Data collected from a two-month sample of daily activity reports showed that administrative time per unit averaged 11.25 minutes per hour and that an average of 7.37 minutes were expended on each call by back-up units. Data from 1975 showed that an average of 15.52 calls per hour were received, so each unit in the 16-beat configuration could expect to service one call per hour. Therefore, the 11.25 minutes per hour administrative time and the 7.37 minutes of back-up time per call were added to the 32.05 minutes service time per call to obtain an adjusted average service time of 50.67 minutes.

It should be noted that adjusting the average service time to account for administrative duties has the disadvantage of making the amount of administrative time computed for each watch dependent upon the number of calls received during each watch. Administrative time, however, may not have such a relationship to the number of calls received. A more accurate method of accounting for administrative time may be through adjustments to the arrival rate of calls for service.

Since the department uses three regular shifts plus an overlay shift, five separate time periods were to be analyzed. Therefore, workload data had to be compiled for each time period. The same overall distribution of workload among the zones was used for each time period. However, separate call rates were computed for each time period based upon 1975 data. Table A-1 shows the five time periods examined, the number of beats previously used, and the average call rates experienced.

Analysis of Old and New Beat Plans

Once trained to operate the hypercube programs, the planners in the Administrative Services Bureau analyzed the performance of the 16-beat configuration. This beat plan is shown in Figure A-7. The conclusions reached from this analysis included the following:

- An overall utilization factor of 0.818 (or 81.8 percent) was computed for the 16-beat configuration, from which the planner concluded that there were sufficient personnel assigned to the patrol division to handle the total generated workload.
- There was a considerable discrepancy between the workloads of certain patrol units and the workloads generated by the beats to which those units were assigned; three of the 16 beats generated workloads that were much lower than the workloads of the units assigned.

Table A-1

CALL RATES AND NUMBERS OF BEATS FOR THE FIVE TIME PERIODS EXAMINED BY THE FRESNO POLICE DEPARTMENT

Time Period	No. of Beats (Old Plan)	1975 Call Rate	Projected Call Rate
7:00 a.m.-3:00 p.m. (Day Shift)	16	15.1	16.0
3:00 p.m.-7:00 p.m. (1st Half of Swing Shift)	16		21.9
7:00 p.m.-11:00 p.m. (1st Half of Lap Shift)	22	21.2	22.4
11:00 p.m-3:00 a.m. (Last Half of Lap Shift)	22	14.8	13.9
3:00 a.m.-7:00 a.m. (Last Half of Midnight Shift)	16		6.3

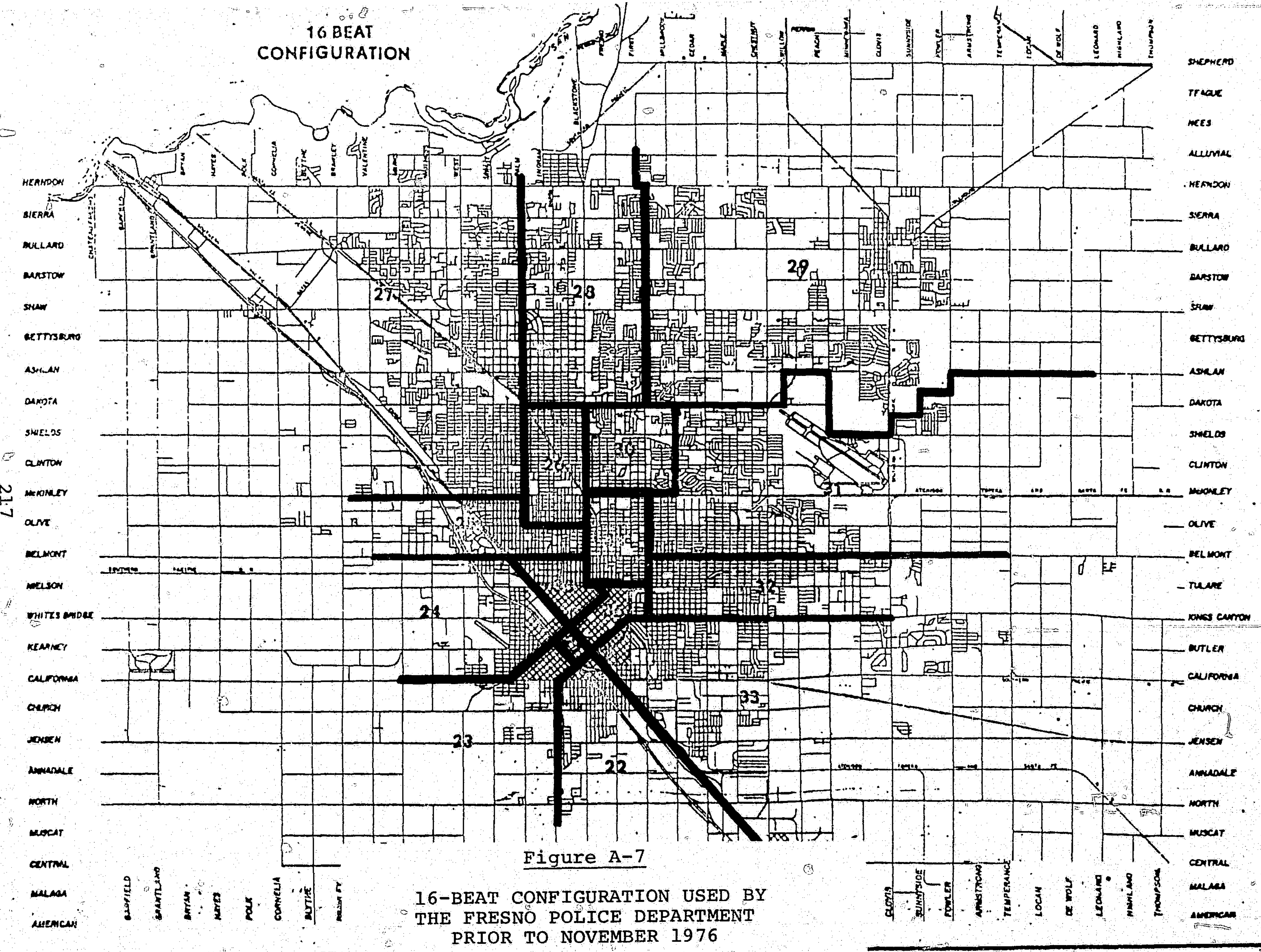

Figure A-7

16-BEAT CONFIGURATION USED BY
THE FRESNO POLICE DEPARTMENT
PRIOR TO NOVEMBER 1976

- There was a substantial imbalance among the beat workloads, even though unit workloads were fairly evenly distributed; for example, the beat workloads on the day shift varied from 0.316 to 1.539.
- Several of the beats were generating more work than could possibly be handled by the units assigned to those beats, so that calls from those beats were consistently serviced by a unit from other beats.
- The average utilization factors computed for the various time periods ranged from 0.33 in the 3:00 - 7:00 a.m. period to over 1.00 in the 3:00 - 7:00 p.m. period.

The redesign process began with a reallocation of manpower to the various shifts. This reallocation had to be planned around the number of beats desired during each of the five time periods being studied. A relief factor of 1.6 was used to calculate the number of men needed for each position. Table A-2 shows the manpower assigned to each shift, and Table A-3 shows the resulting distribution of officers and beats among the five time periods.

Several alternative beat designs were examined for each time period, necessitating numerous hypercube runs. Figures A-8 through A-12 show the final plans for the five time periods. The performance statistics for these plans indicate that workloads are much more evenly distributed, and sufficient officers are assigned during each time period to handle the arriving calls. Estimated region-wide travel times and the number of queued calls during the swing shift are drastically reduced.

One problem encountered in designing the new beat plans was caused by several zones which generate excessively high workloads. As a result, the beats to which they were assigned showed significantly greater-than-average workloads. To reduce the problem,

Table A-2

ALLOCATION OF PATROL MANPOWER
BY SHIFT IN FRESNO

Day Shift (7:00 a.m.-3:00 p.m.)

18 Beats	23 x 1.6 =	37 Regulars
3 Second men in Westside Cars		2 Regulars (Extra)
2 Wagons		2 Mall Officers (Walking Beat)
23 Per Day		41 Total Assigned to Shift

Swing Shift (3:00 p.m.-11:00 p.m.)

23 Beats	31 x 1.6 =	50 Regulars
4 Second men in Westside Cars		2 Recruits (Extra)
2 Westside Walking Beat		52 Total Assigned to Shift
2 Wagons		
31 Per Day		

Lap Shift (7:00 p.m.-3:00 a.m.)

6 Beats	7 x 1.6 =	11 Regulars
1 Second Man in Westside Cars		2 Recruits (Extra)
7 Per Day		13 Total Assigned to Shift

Midnight Shift (11:00 p.m.-7:00 a.m.)

13 Beats	18 x 1.6 =	29 Regulars
3 Second Men in Westside Cars		2 Recruits (Extra)
2 Wagons		31 Total Assigned to Shift
18 Per Day		

TOTAL (All Shifts) = 137 Officers Assigned

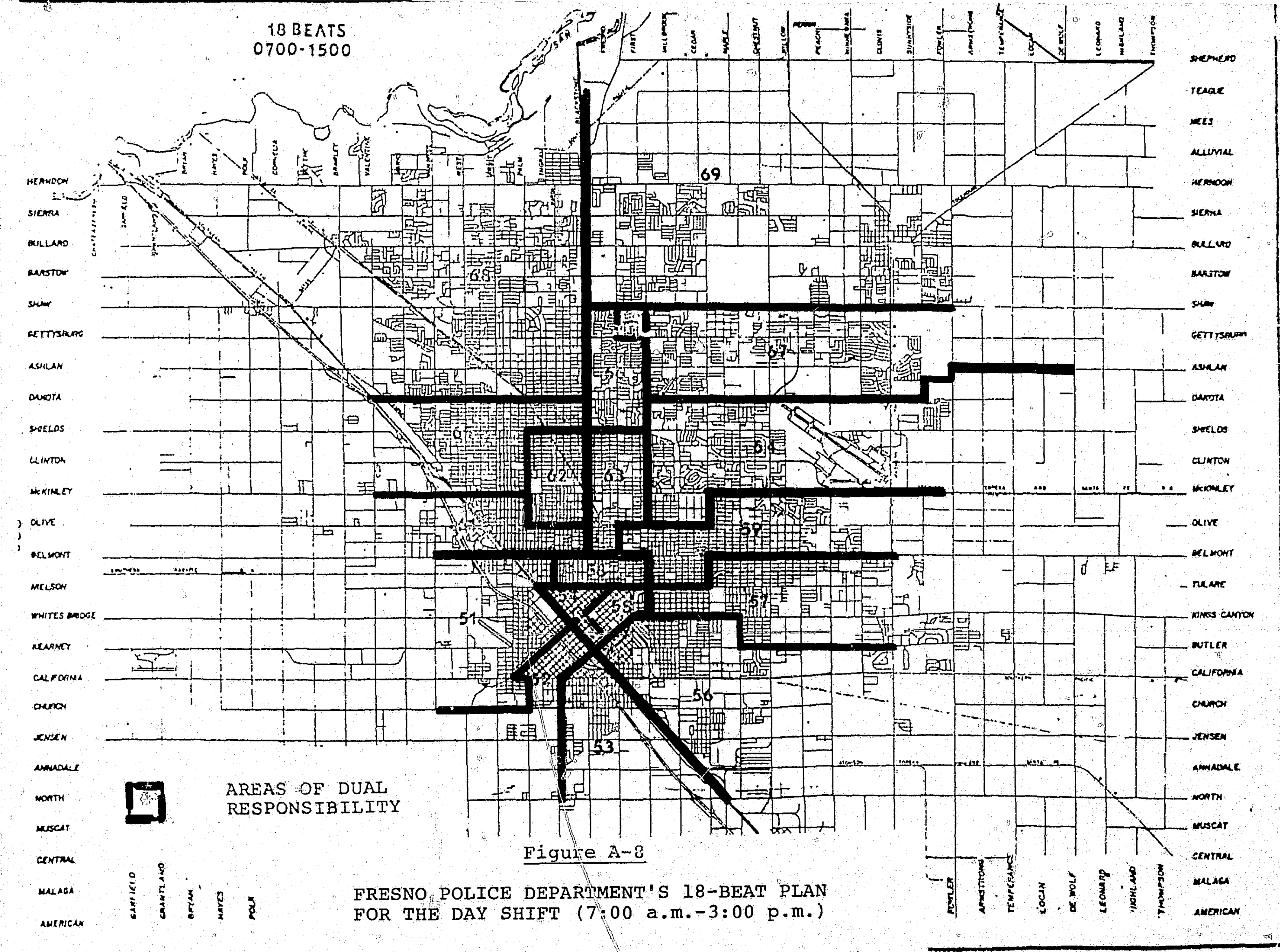

Figure A-8

FRESNO POLICE DEPARTMENT'S 18-BEAT PLAN FOR THE DAY SHIFT (7:00 a.m.-3:00 p.m.)

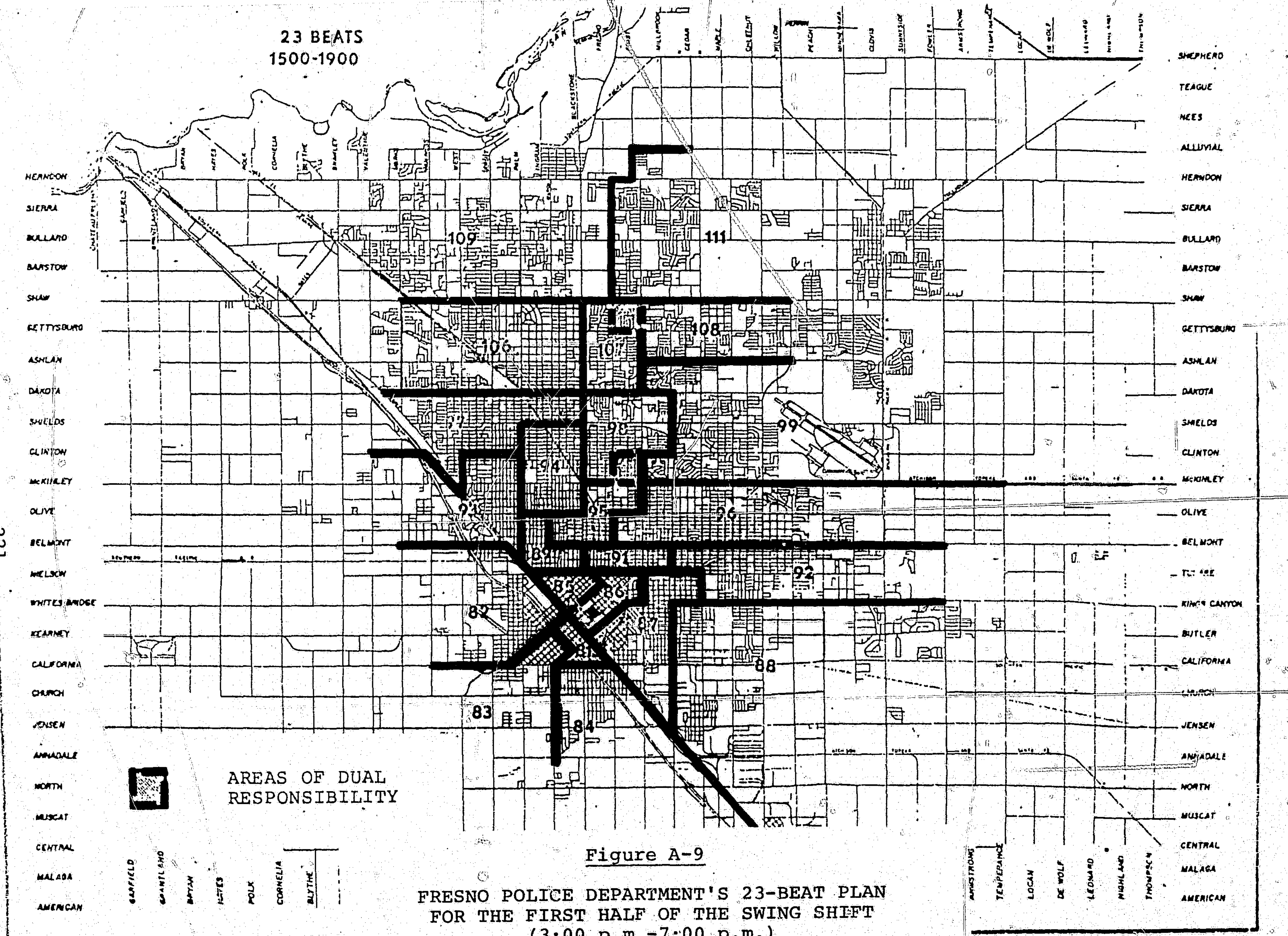

Figure A-9

FRESNO POLICE DEPARTMENT'S 23-BEAT PLAN FOR THE FIRST HALF OF THE SWING SHIFT (3:00 p.m.-7:00 p.m.)

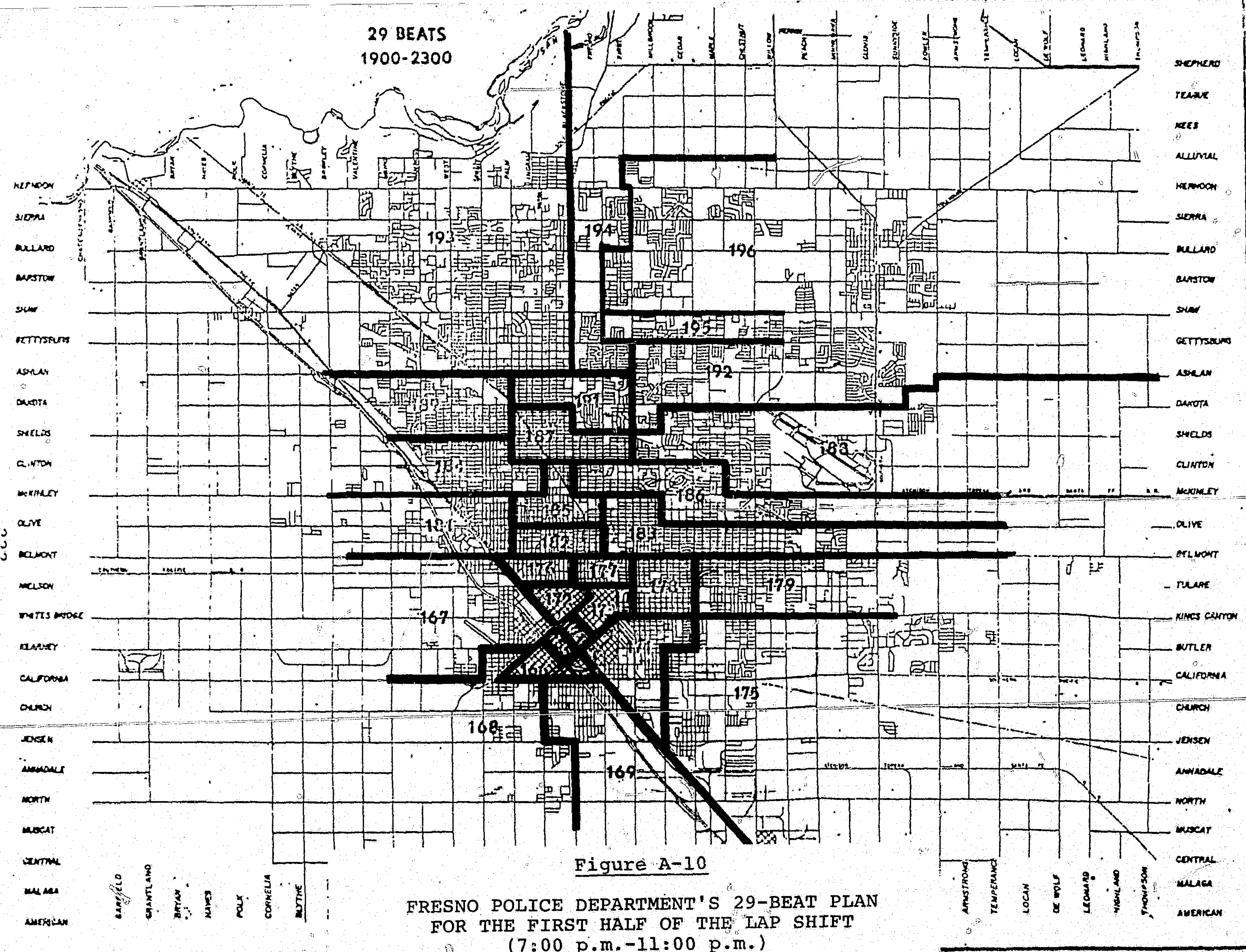

Figure A-10

FRESNO POLICE DEPARTMENT'S 29-BEAT PLAN
FOR THE FIRST HALF OF THE LAP SHIFT
(7:00 p.m.-11:00 p.m.)

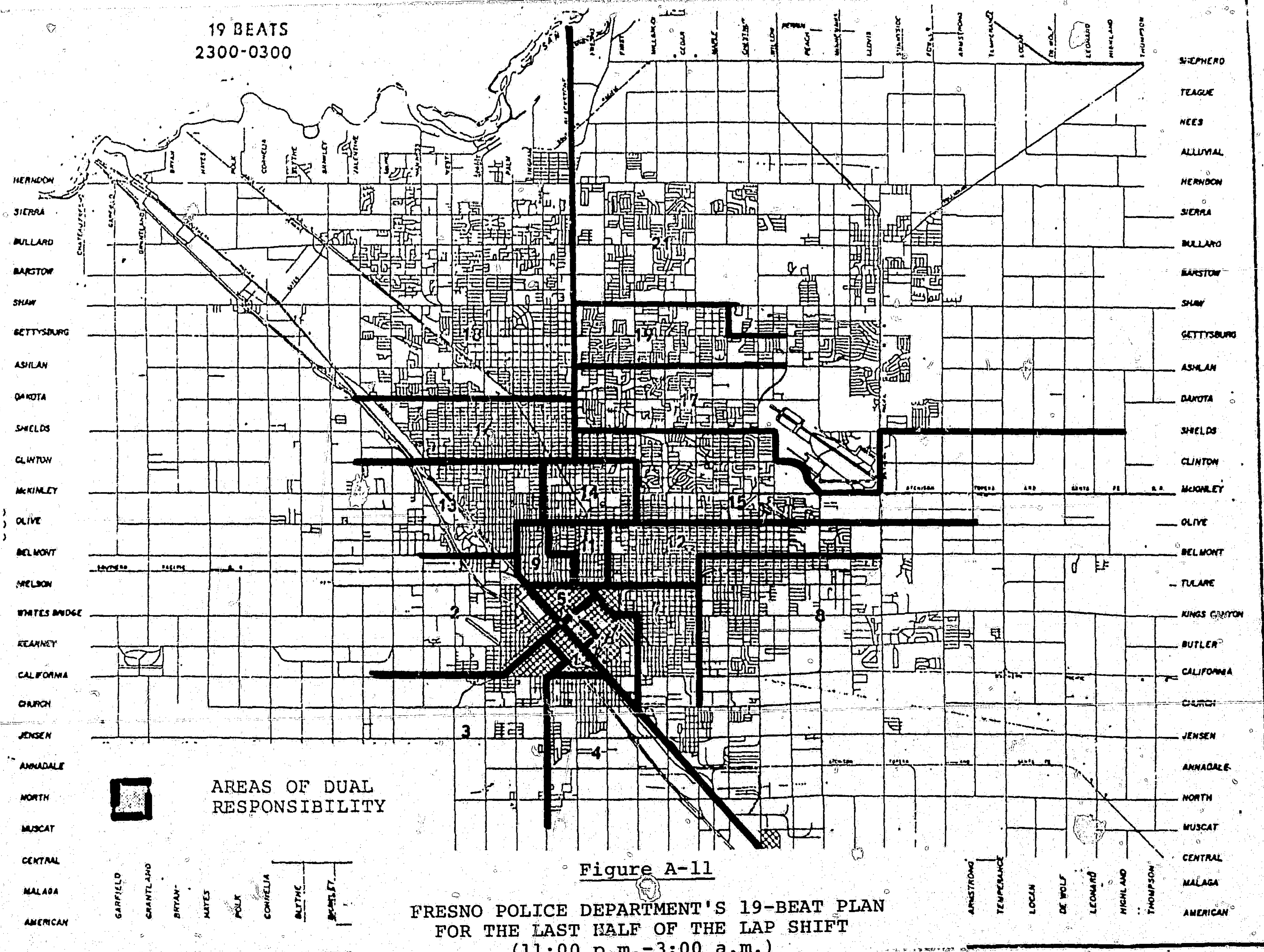

Figure A-11

FRESNO POLICE DEPARTMENT'S 19-BEAT PLAN
FOR THE LAST HALF OF THE LAP SHIFT
(11:00 p.m.-3:00 a.m.)

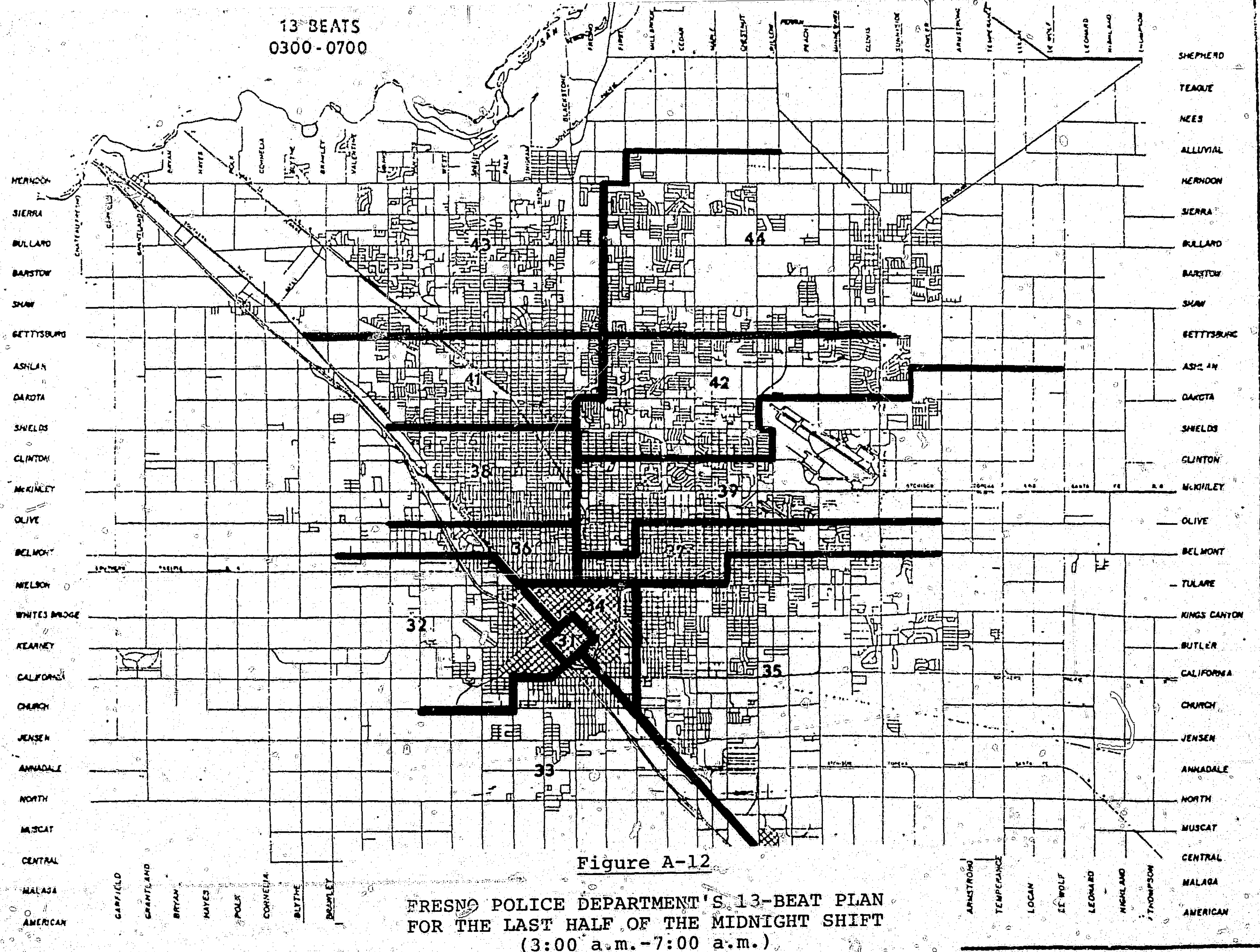

Figure A-12

FRESNO POLICE DEPARTMENT'S 13-BEAT PLAN
FOR THE LAST HALF OF THE MIDNIGHT SHIFT
(3:00 a.m.-7:00 a.m.)

beats were designed to overlap in these zones and back-up units were deployed to assist in these areas.

Implementation of New Beats

Once new beat plans had been designed for the five time periods, a departmental task force was formed to review them. This task force included members of the administrative services bureau, representatives of the patrol division (including watch commanders), a communications representative, and a representative from the police officers' association. Initial hypercube output was presented to patrol division representatives, and several meetings of the task force were held. The beat plans were generally well-received, primarily because of the prospect for more equalized workloads and

Table A-3

FRESNO POLICE DEPARTMENT
PATROL STRENGTH AND NUMBER OF BEATS
BY TIME OF THE DAY

	No. of Men Assigned	No. of Beats
7:00 a.m.-3:00 p.m.	41	18
3:00 p.m.-7:00 p.m.	52	23
7:00 p.m.-11:00 p.m.	65	29
11:00 p.m.-3:00 a.m.	44	19
3:00 a.m.-7:00 a.m.	31	13

response times. Reassignment of some officers to different shifts was not seen as a major problem.

Since a total of 102 beats had been drawn, a new numbering system for identifying beats and assigned units had to be devised. Previously, each beat was designated by a two-digit beat number preceded by a one-digit number indicating the shift (e.g., "224" referred to the second shift, beat 24). Under the new system, the shift numbers were retained, but dispatchers had to familiarize themselves with a different set of beats for each shift. To assist them, assignment cards showing the beat number for each address in the city now show the beat numbers associated with each time period, and separate beat maps were designed for each dispatch console.

The change in the numbering system necessitated changing 20 computer-produced management reports which had been designed to allow only two-digit beat identifiers. The department's CAD system which, when fully operational, will indicate the beat car for any incident address in the city also had to be revised to reflect the new beats at a cost of $900.

Providing sufficient vehicles during peak hours presented an unanticipated problem. At 3:00 p.m., 23 cars are needed, and 29 are needed at 7:00 p.m. Improved scheduling of vehicle maintenance may be needed to ensure that the cars are available when needed.

The patrol division assumed the responsibility of implementing the new beat plans. Beat maps were distributed to patrol officers in September, so they would have at least six weeks to become familiar with the new plans before the November 3 implementation date. The actual implementation proceeded smoothly. The news media was informed of the change, and two newspaper articles have resulted.

Future Use of Hypercube

The Fresno Police Department has been pleased with the results achieved with hypercube, and is considering future use of the programs to periodically assess beat performance. Planning for the CAD system now being implemented required management data similar to that needed for hypercube. As a result, the input data needed for use of the hypercube programs is readily accessible.

Conclusions

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 the 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.

The success of the Fresno effort is particularly noteworthy because of the drastic change made from a beat plan used around-the-clock to plans which vary nearly every four hours. Many departments find such variation in beat plans to be administratively unacceptable, but such a reallocation of patrol resources was necessary in Fresno in order to reduce the excessively high patrol unit workloads previously common to some times of the day.

C. St. Louis County, Missouri

Background

St. Louis County, Missouri, is made up of urban, suburban, and rural areas immediately adjoining the City of St. Louis on the north, west, and south. The eastern area of the county contains highly developed and densely populated suburban communities; the degree of development gradually diminishes to the west, and the extreme western portions of the county are mainly rural and agricultural. There are over 90 incorporated municipalities within St. Louis County, most of which are clustered near the City of St. Louis. The county also contains large unincorporated areas, both developed and undeveloped.

The St. Louis County Police Department provides police services to all unincorporated areas and to those municipalities which contract for such services. The entire county covers 512 square miles with a population of 980,000; the unincorporated area consists of 360 square miles with a population of 360,000. The area served by the County Police Department encompasses both densely populated inner suburbs and the rural west county. The area is divided into five precincts which are patrolled by 41 to 73 units, depending on the time of day.

Designing patrol beats for the St. Louis County Police Department is a difficult task. Each of the five precincts operates as a separate command area and therefore requires a separate beat plan. In addition, all of the precincts vary beat boundaries by watch. To equalize patrol unit workloads, it is necessary to utilize geographically large beats in the west county, resulting in unacceptably high response times. One 50-square mile area produces 30% of the department's calls for service, while another area of 150 square miles produces less than 10% of the calls. One rural west county beat is larger than the entire City of St. Louis.

To aid in the design of patrol beats, the department has a Bureau of Planning and Research with access to large amounts of data. The county is partitioned into 476 geographical reporting areas termed "COGIS" areas (COunty Geographical Information System), and incident data are collected by COGIS area. These areas are aggregated into precincts and beats by planning and research personnel in cooperation with precinct commanders.

Patrol beats are not revised on a regular basis, but they have been redesigned three times in approximately three years, with the most recent redesign of patrol beats taking place in July 1974. Redesign efforts are authorized by the Superintendent of Police, who assigns manpower to the precincts in terms of the number of eight-hour beats that can be manned. (An eight-hour beat is one beat manned eight hours a day, seven days a week.) Precinct commanders are authorized to distribute these eight-hour beats among the three shifts to best handle the workload in their precincts. The precinct commanders and the planning and research bureau usually work together to produce beat plans for each watch, although the commanders can veto any revisions in their beat plans which they find unacceptable.

The department's primary objective in redesigning patrol beats is to balance beat workloads, on the theory that each beat should have an approximately equal share of the department's total workload, regardless of shift or geographical area. However, this objective has never been fully realized, due to the marked differences in response times that would be produced by such workload balancing because of differences in population and workload within the department's jurisdiction. Thus, response times, particularly in the west county beats, is also an important design consideration.

Redesigning all of the beats for the department is a major undertaking simply because a total of 15 plans are required for the five precincts and three shifts. In fact, the 1974 redesign effort consumed an estimated 4,000 to 6,000 man-hours, including 8 to 12 weeks of work by the planning and research staff, and time spent by field and data processing personnel, secretaries, and map makers.

Participation in Field Test Project

When given the opportunity to participate in the field test project, the response within the planning and research bureau was immediately affirmative. Members of the research team met with two representatives of the planning and research bureau in July 1975 to demonstrate the use of the hypercube programs, explain the field test project, and obtain information needed for completion of the project's planning phase. Much of the data neeed to use the programs was readily available in computerized form, and the planning and research bureau had already been given a directive from the Superintendent to produce a new beat design and manpower allocation plan by the end of the year.

The only obstacle to the department's participation was the project's timetable. The actual work of designing new beats in the field test project was not scheduled to begin until after the January 1, 1976, deadline facing the planning and research bureau However, since the department could easily produce most of the necessary input data and was located near TIPPA's offices, arrangements were made for a police planner to use TIPPA's data terminal during November and December for the purpose of analyzing proposed beat plans using the hypercube programs. This helped the planning and research bureau meet its deadline and benefitted the field test project in several ways:

- the research team was able to observe the operation of the hypercube programs using actual police department data;
- existing software and documentation were used by the police planner, and many useful comments and suggestions were obtained;
- the research team was able to closely follow the beat design and review process; and
- the experience resulted in improved plans and training materials for the field test project.

The results of the 1975 beat design effort are described below. Although none of the beat designs produced at that time was implemented, the department continued to participate in the field test project by sending representatives to both the orientation meeting and training-design workshop. In the spring and fall of 1976, the hypercube programs were used to develop beat plans for the first and fifth precincts, respectively, and these beat plans were subsequently implemented. The design and implementation of the new beat plans in these two precincts are also described in later sections of this report.

Use of the Hypercube Programs

The first use of the programs took place in November and December 1975, using TIPPA's data terminal. This redesign had been ordered earlier in the year by the Superintendent of Police, who wanted workloads equalized by precinct, by watch, and by beat. The redesign process consisted of three steps:

- allocation of eight-hour beats to the five precincts according to precinct workloads;
- allocation of each precinct's eight-hour beats to the three shifts according to shift workloads; and
- design of a beat plan for each watch in each precinct.

The hypercube programs were used only in the actual design of beat plans with a total of 15 separate plans produced.

The data used as input to the hypercube system for the 1975 beat design were taken from regular department management reports for the period from January through August 1975. The only major data collection effort required involved measuring the area and plotting the center coordinates for each of the 476 COGIS areas. Computerized data on service times, response times, and called-for and self-initiated work were available by COGIS area. The only drawback to the data used was that they did not reflect workload seasonality in some areas of the county. The use of a nine-month sample, including all of the summer months, ignored the effect of these seasonal variations.

Data collection proved to be a time-consuming task, even though the workload data were computer-generated. A draftsman was utilized to obtain the (x, y) coordinates for the center of each reporting area, and a planimeter was used to obtain each area in square miles; approximately five man-days were required to obtain this information for the five precincts. Approximately two additional man-days were required to enter the geographic and workload data into the computer.

A minor problem resulted from the nonuniformity in COGIS area characteristics. The COGIS areas vary considerably in area, population, shape, and reported workload. Some "hot spots" (e.g., around rural shopping centers) can bias the workload statistics for the COGIS areas in which they are located. This raises the issue of whether reporting areas should be drawn in such a manner as to have equal workloads or equal areas. Also, patrol commanders tend to intuitively overestimate the actual workload of these "hot spots," allocating more patrol units to these areas than necessary to handle arriving calls for service.

Contrary to past practice, the new manpower allocation and beat design effort did not involve the precinct commanders until a meeting was held to present the new plan to them. At that time, they were not told about the use of computerized beat design techniques, because it was felt that there would be a negative reaction to "mathematical management." Nevertheless, there was a strongly negative reaction to the plan presented. The primary objections to the plan included the following:

- the precinct commanders had no input in the formulation of the manpower allocation plan upon which the beat plans were based;
- workload equalization was questioned by some commanders as a suitable allocation and beat design objective;
- questions were raised about the data used to measure workload; and
- there were objections to the actual structure of some beats.

CONTINUED

3 OF 4

The fact that precinct commanders had not been involved in the formulation of the manpower allocation plans was particularly objectionable to those commanders whose precincts would have lost manpower under the new plan. This was a sensitive issue, since some precincts were scheduled to lose manpower despite increases in reported crimes.

The beat design goals of some precinct commanders conflicted with equalized workloads. Equalizing workload by beat produces geographically large beats in low workload areas, which in turn produce greater response times. Some commanders felt that it was necessary to have some low workload areas to which certain officers could be assigned, because of varying levels of performance among officers. Some commanders also felt that no matter how low the workload is in a given precinct on a given watch, there should be some minimum number of units in service.

The planning and research staff had used total service time required by calls for service and self-initiated work as the measure of patrol workload, but some commanders did not see this as an adequate indicator of future workload. The kinds of calls serviced vary considerably by time of day; and long service times for minor incidents during the day tend to overshadow nighttime calls which, although shorter in duration, often deal with more serious types of crimes and frequently lead to arrests. Including self-initiated calls along with radio-dispatched calls was felt to bias workload data in reporting areas served by highly-motivated officers. Also, the commanders doubted the validity of using past data to determine the distribution of future workload.

The actual structure of some beats was also questioned. Some beats were said to be too isolated -- that is, cut off from the rest of the precinct by physical barriers or limited access highways-- making it very difficult to provide rapid back-up assistance to units assigned to those beats. Some commanders objected to the fact that the beat plans were designed independently for each watch. They preferred that the beat plans for busier shifts be obtained by subdividing the beats used for the less busy shifts, with for example, a beat plan first designed for the midnight shift, and the resulting beats subdivided to obtain the beat plans for the day and afternoon shifts. Although this process permits the least amount of flexibility in designing beats for the busiest shift, the resulting beat plans are seen as easier to administer.

As a result of these objections, the new manpower allocation plans and beat designs were not implemented. However, since the hypercube analyses showed two precincts to be inadequately manned due to recent workload increases, a plan was formulated to find ways of increasing the patrol strength in these precincts without cutting the patrol strength in the other precincts. The bureau of planning and research continued to work with the commanders of these two precincts as described below.

Although the 1975 manpower allocation plan and beat design were not implemented, the workload data gathered in the process did show that the first precinct was undermanned. As a result, additional eight-hour beats were allocated to that precinct in the spring of 1976, with new recruits providing the additional manpower so that existing manning levels were maintained in the other precincts.

The hypercube programs were again used in the redesign of beats for the first precinct. The same geographical data were used, but the workload data were changed to include all of 1975. Initially, no adjustment was made in the workload data to account for administrative time--the time during which patrol units are out of service for administrative duties such as briefings, warrant applications, vehicle maintenance, etc. The primary effect this produced was an unrealistically low utilization factor calculated by the hypercube programs. However, since it was assumed that administrative time was equally distributed among the COGIS areas and beats, the relative values of unit utilizations could be used in designing a new beat plan.

Whereas the 1975 plans had been drawn by the planning and research bureau without consulting the precinct commanders, this redesign in the first precinct was accomplished through the joint efforts of a planner and the precinct commander. In fact, the commander designed the tentative plans which were then analyzed using the hypercube programs. New beats were agreed upon and implemented in April 1976.

The final beat plans for the first precinct were later reanalyzed, with the call rate adjusted to account for administrative time. It was found that patrol units spent 20 percent of their time on administrative duties, 60 percent on patrol, 18 percent on call-for-service work, and 2 percent for self-initiated work. Since the amount of time spent on administrative duties was equal to the combined time spent on called-for-service and self-initiated work, the call rate input to hypercube was doubled to give a more realistic picture of patrol workload. The resulting analysis did not, however, show a need to further revise the beat plan.

The 1975 manpower allocation study had also shown the fifth precinct to be undermanned, and a further workload increase was expected to result from the construction of a large shopping center in the west county area. Consequently, the precinct was allocated three additional eight-hour beats in the fall of 1976, necessitating the design of new beat plans.

As in the case of the first precinct, planning and research bureau and precinct personnel cooperated in the redesign effort. Specifically, a planner worked closely with a lieutenant designated as liaison by the precinct commander, and responsible for securing the necessary input from precinct officers. The use of the hypercube programs was fully explained, and hypercube output was shared with the lieutenant, who then explained the findings to other precinct personnel as needed.

One of the problems encountered in designing fifth precinct beat plans was predicting the workload that would be generated by the new shopping center. The development was in a predominantly rural area, which made the problem even more difficult, since the potential workload generated by the center could be much higher than the area immediately surrounding it. Other similar developments in the county had produced considerable workloads in very small areas. Since there was no way to predict the future workload of the center, it was decided that the best course of action was to design a plan based on current data in which the beat containing the new shopping center had significantly lower utilization than other beats.

There was considerable discussion surrouding possible methods of allocating the three additional eight-hour beats. The precinct had previously been allocated a total of 18 eight-hour beats, five of which were allocated to the midnight shift, six to the day shift, and seven to the evening shift. (In shorthand notation, this is known as a 5-6-7 allocation of beats.) Precinct personnel favored allocating one additional beat to each shift, to obtain a 6-7-8 distribution, and they proposed two alternative beat plans for each watch, based upon this allocation. The planner, however, favored a 5-7-9 distribution, and proposed beat plans based on that allocation.

The discussion of the three proposed sets of beat plans centered around which would give the most equitable balance in utilization and response time. The hypercube output for the three sets of plans was examined, and the decision was made to implement the beat plans based on the 5-7-9 allocation.

Future Use of Hypercube

The St. Louis County Police Department has benefitted from using the hypercube programs and would like to continue using them. The benefits derived by the department from participation in the field test project have included the ability to use hypercube to show the trade-offs between the conflicting objectives of balanced workloads and balanced response times. This has been a difficult task for the department in the past, since it serves both high-workload urban areas and low-workload rural areas. Also the system has given planners the capability to consider the effects of the beat plan on interbeat dispatching.

Although the interactive version of the programs is attractive, the cost of renting a data terminal and purchasing computer time from a commercial time-share company may prove to be more than the department is willing to invest in designing patrol beats. An alternative would be to implement the hypercube programs on the computer facilities of the Regional Justice Information System, an agency which provides data processing services for criminal justice agencies in the St. Louis area. However, this would require additional training in using a non-interactive version of the software. The departure of the planner trained to operate the system might seriously jeopardize plans for continued hypercube use.

Conclusions

Several of the tentative guidelines suggested during the planning stage of the field test project have been validated in the experience of the St. Louis County Police Department. These are as follows:

- There is a need for agreement on the objectives to be used in designing beats. The hypercube programs assume that in the iterative design process the planner has a set of goals and preferences with which to trade off conflicting objectives.

- There is a need to have agreement on a manpower allocation plan prior to initiating the beat design process. The hypercube programs can be used to test various ways of distributing manpower to precincts and working shifts, but this is tedious and time-consuming. The design process is greatly enhanced if there is prior agreement on the number of beats to be designed.

- Field commanders having the responsibility for implementing and supervising patrol operations need to be involved in the beat design process.

- Advance planning and an assessment of the data needed can produce reasonable estimates of the time and resources involved in beat design. It is very important to review all of the data, procedures, and time that will be required. Data collection can be especially time-consuming. An accurate appraisal of how many plans are needed, the time-frame within which the job must be completed, and the turnaround capabilities of the computer can be invaluable in estimating the total time and resources required.

APPENDIX B

KEY PROJECT PARTICIPANTS

1. National Science Foundation, Program Managers

Dr. Neil Dumas
Ms. Lynn Preston
Dr. David Seidman

2. Project Advisory Board

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

3. California Innovation Group, Science Advisors

Nick Davis and Warren Deutsch, Santa Clara
Acey Floyd, Burbank
Owen Griffith, Anaheim
Mathew King, Garden Grove, Huntington Beach, and Santa Ana
Michael Licciardello and Dennis Megrditchian, Fresno
Gerald Miller and Allen Sjoholm, San Diego
Forrest Warren, Pasadena
Jerome Weiss and Robert Rosenberg, San Jose

4. Massachusetts Institute of Technology, Research Team

Dr. James J. Jarvis
Dr. Richard C. Larson
Richard W. Weissberg

5. Participating Police Departments

a. Burbank, California

Chris Dosevski
Bud Giles, Records Supervisor
Capt. Robert Heins
Frank Taylor

b. Fresno, California

Sgt. Max Downs
Sgt. Earl Kaundart
Deputy Chief James Packard

c. <u>Garden Grove, California</u>

Terry Mathers, Administrative Analyst

d. <u>Huntington Beach, California</u>

Sgt. Robert Fickle

e. <u>Pasadena, California</u>

Lt. James Robenson
William Slater, Planning and Research

f. <u>St. Louis County, Missouri</u>

James Gardner, Bureau of Planning and Research
Richard Valdez, Bureau of Planning and Research

g. <u>San Diego, California</u>

Sgt. Jon Kern
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Lt. David Spisak
Sgt. Peter Zadorozny

h. <u>San Jose, California</u>

Lt. Robert Bradshaw
Capt. Stanley Horton
Sgt. Tom Johnson
Ms. Elba Lu

i. <u>Santa Ana, California</u>

Lt. James Picco
Sgt. Rodney Qualls

j. <u>Santa Clara, California</u>

Chief, Donald Ferguson
Capt. Loren Pierce

6. <u>Other Participants</u>

Russell Arend, Director of Training, Traffic Institute, Northwestern University
Lee Johnston, San Diego Comprehensive Planning Organization
Palmer Stinson, Project Consultant
John Cochran, San Diego Sheriff's Department

APPENDIX C

OBTAINING HYPERCUBE PROGRAMS, DOCUMENTATION, TRAINING, AND TECHNICAL ASSISTANCE

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, and to date 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.

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

- Interactive or non-interactive - does the system include an interactive component which 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?

- Computer programming language used - is the software written in PL/I or in COBOL? (This is an important difference since some computer systems may not accept programs written in one or both of these 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?

These differences among the four hypercube systems are summarized in Table C-1.

The primary sources of these four versions of the hypercube computer programs, documentation, training, and technical assistance, and the materials and services obtainable from each source, are identified below. Inquiries regarding the cost and availability of the materials and services identified should be directed to the source listed.

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

Copies of all four versions of the hypercube software can be obtained from The Institute for Public Program Analysis (TIPPA). The TIPPA version, written in the PL/I programming language, contains all features and capabilities added during the field test project. Related software facilitating the use of the hypercube system on National CSS (NCSS), an internationally accessible, commercial time-share data processing system, is also available. The TIPPA version and the NCSS software are documented in the report:

"Instructional Materials for Learning to Use the Hypercube Programs for Analysis of Police Patrol Operations".

Table C-1

CHARACTERISTICS OF CURRENTLY AVAILABLE VERSIONS OF THE HYPERCUBE SOFTWARE

	Software Option			
	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*	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

*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.

The following TIPPA reports are also available to persons interested in the results of the field test project, or in using the hypercube model to analyze their own department's patrol operations:

- "How to Set Up Shop for Use of the Hypercube System"; and
- "Field Evaluation of the Hypercube System for the Analysis of Police Patrol Operations: Executive Summary"

TIPPA provides training for new hypercube users during a periodically-held 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 NCSS time-share system.

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

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

B. <u>The Rand Corporation</u>
1700 Main Street
Santa Monica, California 90406
Attention: Dr. Jan Chaiken
(213) 393-0411

Copies of the M.I.T./Rand and Texas A&M versions of the hypercube software can be obtained from The Rand Corporation (Rand). The M.I.T./Rand version of the software, written in PL/I, is documented in the report:

"Hypercube Queuing Model: User's Manual," R-1688/2-HUD.

Other related reports available from Rand include:

- "Hypercube Queuing Model: Executive Summary," R-1688/1-HUD;
- "Hypercube Queuing Model: Program Description," R-1688/3-HUD;
- "The Deployment of Emergency Services: A Guide to Selected Methods and Models," R-1867-HUD; and
- "Patrol Allocation Methodology for Police Departments," R-1852-HUD.

Rand also distributes software and documentation for its Patrol Car Allocation Model (PCAM), used for determining the number of patrol cars that should be on duty in each geographical region of a city at various times of the day on each day of the week.

Neither technical assistance nor training are offered.

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

Copies of all four versions of the hypercube software are available from M.I.T. The M.I.T. version is documented in the user's manual:

- "Computer Program for Calculating the Performance of Urban Emergency Service Systems: User's Manual," TR-14-75.

Other reports available from M.I.T., which describe various aspects of police patrol policy analysis and beat design, include the following:

- "Urban Public Safety Systems - Volume I," Dr. Richard Larson, et al., Lexington Books, Lexington, Massachusetts, 1977;

- "Optimal Dispatch Policies for Urban Service Systems," TR-02-73;
- "Optimization in Stochastic Service Systems with Distinguishable Servers," TR-19-75;
- "The Hypercube Model: An Introduction to Its Structure and Utility," TR-20-75;
- "Dispatching the Units of Emergency Service Systems Using Automatic Vehicle Location: A Computer-Based Markov Hypercube Model," TR-21-76;
- "Merging Interest Group Preferences for Emergency Services with Applications to Police Sector Design," TR-22-76;
- "A Hypercube Queuing Model for Facility Location and Redistricting in Urban Emergency Services," JR-06-74;
- "Illustrative Police Sector Redesign in District 4 in Boston," JR-08-74;
- "Approximating the Performance of Urban Emergency Service Systems," JR-12-75;
- "An Interactive Approach to Police Sector Design," WP-03-74; and
- "Data Collection and Computer Analysis for Police Manpower Allocations," WP-14-74.

M.I.T. offers a one-week seminar annually, entitled "Analysis of Urban Service Systems," in which one day is devoted to the hypercube system. Only limited technical assistance is offered by M.I.T. It is locally available, however, from Public Systems Evaluation, Inc. and Urban Sciences, Inc. (see below).

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

Copies of the Patrol Officer Deployment System (PODS) software package are available from the 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. The package contains, in addition to the Texas A&M version of the hypercube software, 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. The system is documented in the following reports:

- "Police Officer Deployment System (PODS)," TEES 1056-76-1;
- "Police Officer Deployment System: User's Manual," TEES 1056-76-2;
- "Police Officer Deployment System: Long Range Deployment Subsystem Programmer's Manual"; and
- "Police Officer Deployment System: Tactical Deployment Subsystem Programmer's Manual".

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

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 software are available.

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

Copies of the M.I.T./Rand version of the hypercube software are available from the National Technical Information Service (NTIS Order Number PB 259 882). Software documentation is also available. No training or technical assistance are offered.

G. Management Consulting Firms

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

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

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

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

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

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

Dr. Nilsson has developed an adaptation of the M.I.T./Rand version of hypercube software for use by police departments in less urbanized areas such as many of those 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.

I. DeKalb County Police Department
Data Processing Department
Court House Square
Decatur, Georgia 30030
Attention: Mr. William Gaston

The DeKalb County Police Department has developed a computer-based mapping system which, while independent of the hypercube software, could enable hypercube users to produce maps on a line printer showing, for example, the size and location of police patrol districts, the workload distribution among reporting areas, and the distribution of preventive patrol among reporting areas. The software is documented in the report:

"Instruction Manual, The DeKalb County Computer Mapping System".

Neither technical assistance nor training are available.

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

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

END