INSTRUCTIONAL MATERIALS FOR LEARNING TO USE THE HYPERCUBE PROGRAMS FOR THE ANALYSIS OF POLICE PATROL OPERATIONS

THE INSTITUTE FOR PUBLIC PROGRAM ANALYSIS

ST. LOUIS, MISSOURI 63105

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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 hypercube system is a computerized planning tool used to evaluate alternative police beat structures and patrol deployment policies. The study was conducted by The Institute for Public Program Analysis in cooperation with the California Innovation Group (an NSF-funded consortium of cities active in technology transfer) and police departments in St. Louis County, Missouri, and the California cities of Burbank, Fresno, Garden Grove, Huntington Beach, Pasadena, San Diego, San Jose, Santa Ana, and Santa Clara.

This report has been designed for use as a handbook for a short training program for police planners about the use of the hypercube computer programs for the design and analysis of police patrol operations. Principal topics covered include: a review of concepts applicable to planning police field operations; criteria used to compare alternative patrol district designs; the advantages, limitations, and basic assumptions of the hypercube method; a description of the input data required for use of the hypercube computer programs, and of methods for obtaining it; operation of the computer programs using a time-share computer service accessed via telephone by an electronic data terminal, including how to input the data, how to interpret the output statistics, and how to modify a district design to obtain a "better" configuration; and use of the hypercube programs to resolve policy issues more complex than location of patrol district boundaries (e.g., how to compare field performance when patrol cars are assigned to specific districts with that when they are not).

PREFACE

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- a review of concepts applicable to planning police field operations;
- criteria used to compare alternative patrol district designs;
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- operation of the computer programs using a time-share computer service accessed via telephone by an electronic data terminal, including how to input the data, how to interpret the output statistics, and how to modify a district design to obtain a "better" configuration; and
- use of the hypercube programs to resolve policy issues more complex than location of patrol district boundaries (e.g., how to compare field performance when patrol cars are assigned to specific districts with that when they are not).

The text includes a series of district design exercises designed to provide each trainee with experience in the use of the data terminal and the hypercube computer programs. Also included are reference charts and tables which summarize hypercube's command terminology and briefly outline the required procedures for running the programs. Once familiar with the text users will find this reference material handy for routine use of the programs.

Some of the material presented in this text is in outline form, and is intended to be supplemented during each training program session with detailed discussions led by an instructor knowledgeable in police resource allocation methods and in the use of the hypercube programs.

In addition to this text, it is suggested that trainees obtain the following related documents:

(1) "Hypercube Queuing Model: Executive Summary," R-1688/1-HUD

(2) "Hypercube Queuing Model: User's Manual," R-1688/2-HUD

(3) "Field Evaluation of the Hypercube Programs For Analysis of Police Patrol Operations: Final Report"

(4) "How To Set Up Shop For Use of the Hypercube System," and

(5) "Criminal Justice Models: An Overview," R-1859-DOJ.

Items (1), (2), and (5) are available from the Rand Corporation, Publications Department, 1700 Main Street, Santa Monica, California, 90406. Items (3) and (4) are available from The Institute for Public Program Analysis, 230 South Bemiston Avenue, Suite 914, St. Louis, Missouri, 63105. A considerable amount of additional documentation on the hypercube model and programs is available from the M. I. T. project team which developed hypercube. A list of these reports is given in the bibliography at the end of the text. Inquiries regarding these reports should be directed to Dr. Richard Larson, Laboratory for Architecture and Planning, Massachusetts Institute of Technology, Cambridge, Massachusetts, 02139. Much of the material in this text draws on information contained in these reports. Additional useful material has been adapted from "A Training Course in Deployment of Emergency Services: Instructor's Manual," by Chaiken, Ignall, and Walker.

Throughout this report, detailed, step-by-step procedures for performing basic computer operations have been included, (e.g,, accessing the computer programs via the data terminal and creating the necessary input files). These procedures reflect data processing conventions in effect at the time-share computer service selected for the initial presentation of this training program in June 1976. This service, supplied by National CSS, Inc.,* of Norwalk Connecticut, was selected by The Institute for Public Program Analysis after a comprehensive review of the cost and convenience of operating the hypercube programs on a number of time-share systems. Users wishing to operate the programs on a time-share service other than National CSS will have to substitute appropriate data processing conventions and procedures in place of many of those given here. In the discussions which follow, and in other reports produced for this project, the time-share computer service is sometimes referred to as the "central site data processing service." This is because the actual calculations performed by the hypercube programs take place at the service's centrally located computer facilities, with only input and output being performed at the data terminal.

The training program is designed to take advantage of the tutorial and error-correcting capabilities offered by the "interactive" version of the hypercube programs. In this version the user is led by the computer through a step-by-step question and answer procedure for inputting data and obtaining the results of hypercube analyses. This version of the programs can only be

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

operated using data terminals and time-shared data processing. Once trained in use of the hypercube beat design method, some planners may prefer to use another version of the hypercube programs, called the "batch" version, which does not utilize a data terminal for input and output. Although the batch version consequently lacks the tutorial and error-correcting capabilities of the interactive version, it can be installed on some of the computers now used by police departments -- a capability not now available with the interactive program (most such police computers support neither the time-share nor the data terminal operations required). Users of the batch program will find complete instructions for its operation in items (1) and (2) listed above.

The hypercube queuing model of police field operations was first formulated by Dr. Larson about 1969 in connection with his doctoral dissertation research. In subsequent research projects headed by Dr. Larson, funded by the Department of Housing and Urban Development and by the National Science Foundation (Research Applied to National Needs Program), the capabilities of the model were expanded and the initial hypercube computer programs were written. Since these first computer programs were developed, numerous improvements have been incorporated into them, including many made by The Institute for Public Program Analysis based on its field tests of earlier versions. The software documented in this text embodies all the capabilities available and tested at the time the text was prepared (December 1976). Other, more powerful versions of the software are likely to emerge from current research on the hypercube model, which includes study of:

- procedures for automatic sequential improvement of a district plan by selection and transfer of reporting areas among districts;
- an improved technique for accounting for patrol-initiated (non-called-for-service) work performed by patrol units;
- a method for computing travel times when barriers such as rivers or expressways lead to detours of considerable length; and
- a procedure for modeling two priority classes of incoming calls-for-service (e.g., "now" or emergency calls, and routine calls), rather than treating all calls as if they were the same priority.

Users seeking information on recent software improvements should direct their inquiries to Dr. Larson at the address given above.

The terminology used to describe police patrol operations varies considerably among police departments. For this reason, a glossary of police terms has been included in Appendix A. To clarify the discussions which follow, some of the most essential definitions are repeated here:

district - an area in which one patrol unit has (usually exclusive) preventive patrol responsibility. When districts overlap, such responsibility is no longer exclusive, but each car's district is the area in which it is expected to perform preventive patrol.

region - a group of districts administered as an autonomous field operations territory (i.e., cars in one region are rarely dispatched to respond to calls in another region).

reporting area - a subarea within a district, sometimes no more than a few city blocks in size, that is used as the smallest geographical unit for aggregating statistics on the spatial distributions of calls for service and preventive patrol coverage. Reporting areas are the geographic building blocks with which districts are constructed.

These terms are used throughout this text. Since many synonyms for them exist, readers should carefully relate "district," "region," and "reporting area" to the corresponding terms used in their own police departments before reading the rest of this document.

The authors would like to acknowledge the assistance given them in preparing this text by the police planners who participated in the initial presentation of this training program and then later used the text as a reference book when operating the hypercube programs in their police departments. Police departments which participated included Burbank, Fresno, Garden Grove, Huntington Beach, Pasadena, San Diego, San Jose, and Santa Ana (in California), and St. Louis County (in Missouri). Lt. John A. McQueeney of the San Diego Police Department, and William Slater of the Pasadena Police Department, later contributed very useful suggestions for improving the first draft of the text, many of which were incorporated in the present version. The authors would also like to acknowledge the support given to the present project by the National Science Foundation, and Research Applied to National Needs program. Dr. David Seidman and Ms. Lynn Preston, and Dr. Neil Dumas, all of NSF, contributed valuable suggestions throughout the project.

The authors would also like to acknowledge the assistance of the staff of the Massachusetts Institute of Technology's Innovative Resource Planning Project. Particularly helpful were Dr. Richard Larson, Dr. James Jarvis, and Mr. Richard Weissberg.

TABLE OF CONTENTS

Page

Page

I. Introduction to Planning Police Field Operations

1. Police Patrol Operations

This text is concerned with methods of planning the deployment of police patrol units which have responsibility for responding to calls for service, and for preventive patrol (or routine surveillance) when they are not otherwise occupied handling calls. Figure I-1 diagrams the major event sequences in the activities of these patrol units and of the dispatchers who give them their assignments.[12] Another view of the event sequence involved in the arrival and servicing of calls for police service is shown in Figure I-2.[12] Both figures provide a convenient framework for discussing police patrol operations in general, and for highlighting the features of these operations which can be studied with the hypercube queuing model.

2. Features of Patrol Allocation Plans

A complete plan for allocating or deploying patrol units to "cover" a specified jurisdiction usually deals with the following issues:[11]

- number of men on duty
  - variation by day of week and/or season
  - variation by time of day
- mode of patrol
  - one-man cars
  - two-man cars
  - scooters or motorcycles
  - foot patrols
  - other (e.g., canine, evidence collection)

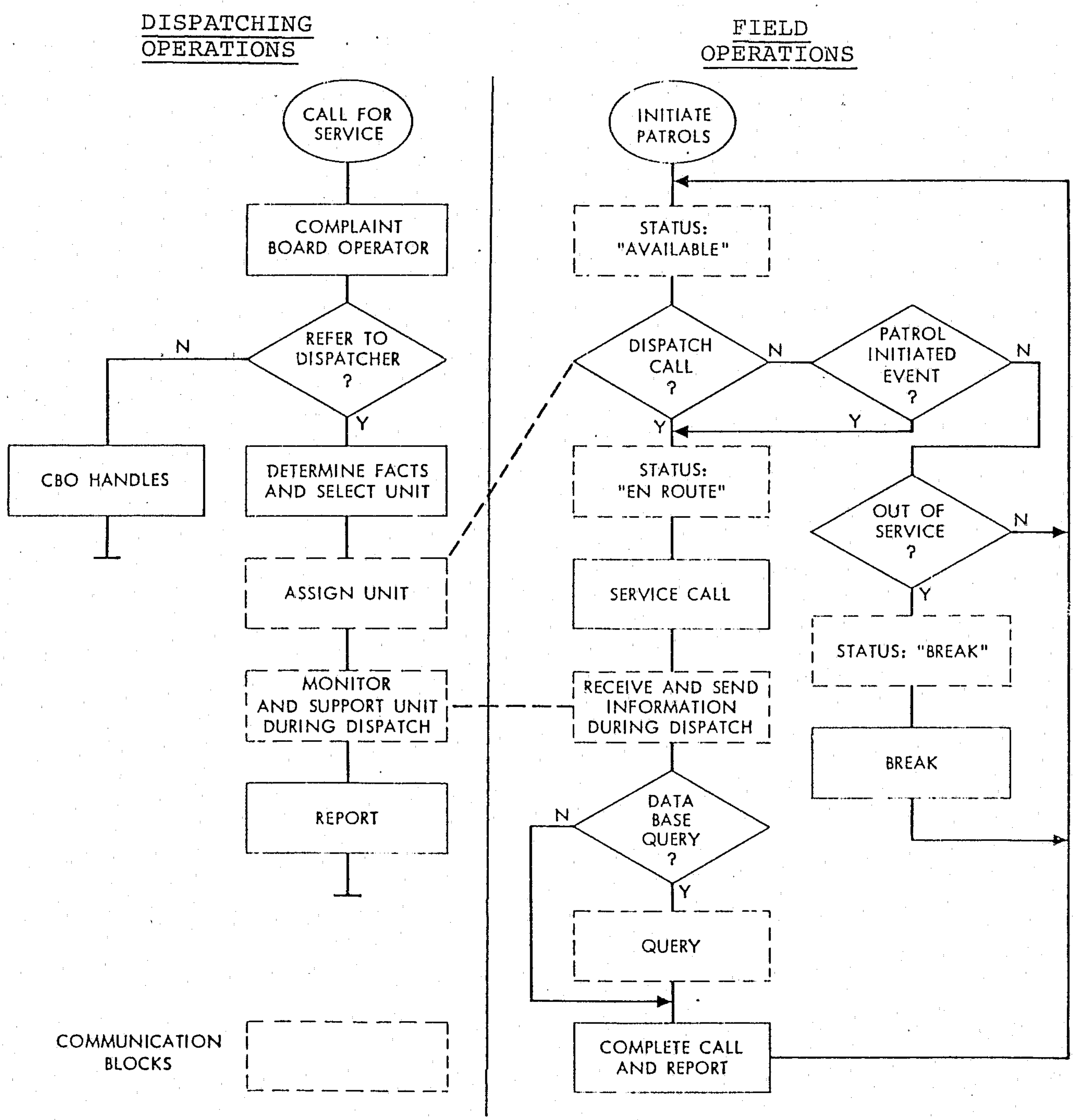


Figure I-1

EVENT SEQUENCES FOR DISPATCHING AND PATROL OPERATIONS

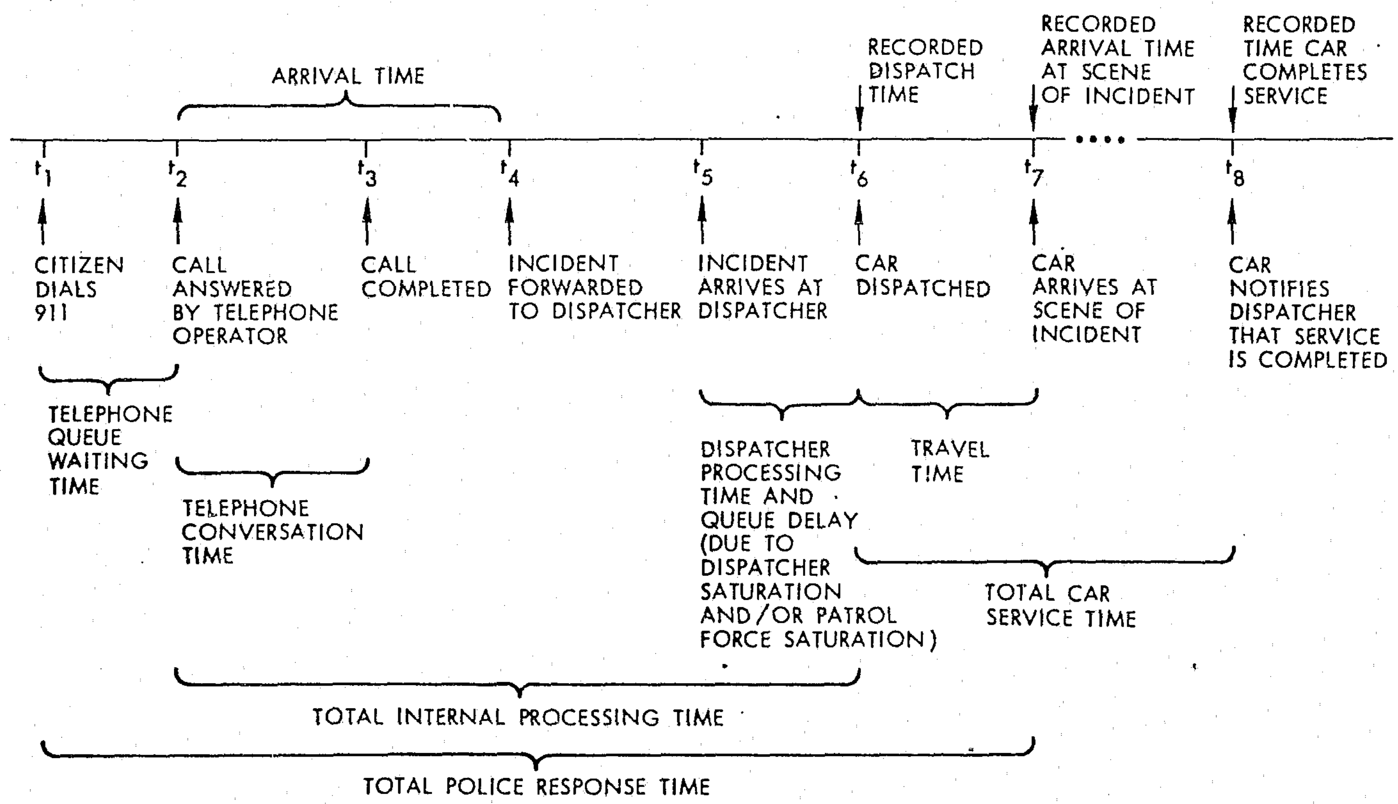


Figure I-2

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

- o number of units in each geographical region
- o design of patrol districts for each unit
- o when calls are queued (stacked, backlogged)
  - -- variation with type (priority) of call
- o number of units dispatched
  - -- variation with location
  - -- variation with type (priority) of call
- o which units dispatched
  - -- type
  - -- closest unit?
  - -- district car?
  - --across region boundaries?
- o redeployment as unavailabilities occur
- o manpower scheduling
- o scheduling of "other" unavailabilities
- o alternative uses of priorities assigned to calls for service
  - -- if queue forms, dispatch free unit to oldest high priority call (The average delay for all calls remains unchanged, but the average delay for priority calls is decreased.)
  - -- hold one or two units (regular or special units) in reserve for high priority calls (The average delay for all calls is increased.)
  - -- screen out low priority calls when busy (an "adaptive" dispatch policy)
  - -- schedule low priority calls for handling at a more convenient time

3. Criteria Used in Assessing Patrol Allocations

Police administrators, police patrol officers, and members of the public use a wide range of criteria in assessing patrol allocations. The most commonly used include:

- length of time a caller must wait until a unit is dispatched
- travel time to the scene of the incident
- dispatches of patrol units out of their assigned areas
- balance of workload among units
- time available to patrol units for other patrol activities
  - -- preventive patrol
  - -- meals and personal breaks
  - -- patrol-initiated investigation
  - -- traffic
  - -- maintenance of vehicle
  - -- interaction with citizens
- cost
  - -- labor costs including salaries and overtime
  - -- equipment costs (e.g., vehicles)
- ability to supervise patrol manpower
  - -- unity of command
  - -- neighborhood integrity
  - -- simplicity of geographic deployments
  - -- simplicity of work schedules
- officer safety considerations
  - -- availability of backup assistance

- -- ease of communication with dispatchers
- -- availability of vehicle location information

o officer morale considerations

o adequacy of patrol coverage of "hot spots" and areas having special crime problems

o citizen expectations regarding speed and level of police response

o impact of the patrol allocation on other services required of the police department (e.g., investigations, records, etc.)

o relation to radio communication system

- -- number of channels
- -- voice or digital

o relation to services demanded by active public interest groups and influential citizens

4. Problems With Manual Allocation of Police Manpower

Decades ago important advances in the allocation of police patrol manpower were made as many police departments initiated routine procedures for compiling information on where and when calls for service and crimes were occurring. This information made possible the assignment of patrols to districts and watches in proportion to the anticipated workload or crime hazard. Two popular allocation procedures used then, and still used by many departments today, are based on a "hazard formula" and a "workload formula."[11]

o description of hazard formula

- -- F_j = j^{th} factor
- -- examples of factors:

  Number of outside violent crimes
  Number of other Part I crimes

Number of street miles
Number of arrests
Number of commercial establishments
Number of emergency calls

-- f_{ij} = amount of factor j in region i

-- $F_j = f_{1j} + f_{2j} + f_{3j} + \ldots + f_{Nj}$

-- w_j = "importance" of factor j

-- $H_i = w_1 \frac{f_{i1}}{F_1} + w_2 \frac{f_{i2}}{F_2} + \ldots + w_M \frac{f_{iM}}{F_M}$

-- manpower proportional to H_i

o description of workload formula

-- w_j = number of man-hours associated with factor j

-- $H_i = w_1 f_{i1} + w_2 f_{i2} + \ldots + w_M f_{iM}$

-- manpower proportional to H_i

-- mathematically the same as hazard formula with different weights

o problems

-- apples and oranges

-- interrelated

-- proportional increase for emergency calls

-- no way to determine "correct" weights for hazard formula

-- workload formula accomplishes only one objective: equalizing workload

-- hazard formula <u>does not do</u> what it appears to do

example: assume regions with high numbers of outside crimes have proportionately more unimportant calls. Then <u>increasing</u> w_j for outside crime <u>decreases</u> manpower assigned to high-crime regions.

-- no credit for good performance

o may be useful for manpower needs <u>other than patrol</u>

Workload and hazard formulas have been popular, not only because they take into account where and when police services are needed, but also because all the needed calculations can be performed by hand or with a desk calculator. Such manual allocation procedures, however, have a number of drawbacks (in addition to those already listed):

- o the calculations can be very tedious and time consuming (and therefore expensive)
- o if several alternate deployment plans are under consideration, the time (cost) required to make the needed calculations is correspondingly increased
- o only a limited number of performance criteria can be estimated manually
- o practically speaking, only a limited amount of field operations performance data can be utilized in a manual analysis, even if much more is available
- o the development of charts and figures summarizing the results of a manual analysis is also time consuming
- o only a limited number of deployment constraints can be accounted for in a manual analysis.

5. <u>Mathematical Models of Patrol Operations</u>

Beginning around 1960 mathematicians and police planners began to work together to construct analytical methods for studying police patrol operations. These methods made use of "modeling" techniques long used in other areas of science.[11]

- o definition of model: abstraction of reality. Used to gain insight into, and answer questions about, the real world. Easier, safer, and less costly to use than manipulating real world
- o <u>empirical models</u>
  - -- fit to data
    - .. May have no explanation
    - .. May be mathematically complicated

-- examples
  .. smooth fit to call rate by time of day
  .. how long to travel a given distance
  .. relationship between fraction of time cars are unavailable and number of calls for service

- <u>descriptive analytical models</u>

  -- using simplified assumptions, some kind of mathematical formula is derived to permit estimating some performance characteristic(s)

  -- the numbers that go into such a model may come from empirical models

  -- examples
    .. knowing number of units on duty, estimate average travel time to an incident
    .. knowing number of units on duty, estimate fraction of serious emergencies encountering a delay before dispatch
    .. knowing the patrol area of each unit and location of incidents, estimate workload and fraction of out-of-district dispatches for each unit

  -- (the hypercube model is a descriptive analytic model)

- <u>optimization models (prescriptive)</u>

  -- tell how to achieve the most or the least of something

  -- examples
    .. how should districts be designed to <u>minimize</u> average travel time to incidents?
    .. how should a fixed total number of man-hours be distributed amoung tours so as to <u>minimize</u> the chances that a caller will have to wait before dispatch of a patrol car?

- <u>simulation models</u>

  -- imitate patrol operations step by step

  -- collect all kinds of statistics

  -- can be extremely accurate

  -- don't tell you what to do

  -- things you try will be suggested by other models

  -- likely not to be useful until close to the end of analysis; but have to start early to collect data

- why police deployment models often do not include explicit consideration of crime deterrence, arrests, property recovery, or community sense of security

  -- hard to measure

  -- relationship to allocation not known precisely enough

  -- we use proxy measures

  -- administrators can tell what changes in performance measures (up or down) are desirable, even if they don't know the exact benefit

6. Computer-Based Models of Patrol Operations

The hypercube queuing model is one of a number of computer-based models of patrol operations developed in the last decade. The reliance on computers to perform the mathematical calculations needed to use these models has occurred because:

- computers can solve complex mathematical problems with great speed
- modern computers have exceedingly large storage capacities and can therefore utilize enormous amounts of pertinent data
- many of the calculations required by the patrol models are too complex and time consuming to be made manually
- many police departments now have routine access to data processing services
- computer printouts can serve as charts, tables, or maps without additional work
- many more alternate deployments can be analyzed than when working by hand
- computer-based analyses sometimes are considered more reliable than those done manually (the reverse is sometimes also true), and
- many computer programs may be useful even if the user does not have a comprehensive understanding of how their calculations are performed.

a. Batch vs. interactive models

Most computer-based models are embodied in computer programs run in a "batch mode," which involves inserting the program and related data in a job queue at the data processing facility. The jobs are then run as time permits, and results are normally recorded on standard computer printout paper. Some models, however, have the useful capability of being operable in an "interactive mode" in which the user communicates directly with the computer via a remote teletypewriter terminal. These models often include tutorial and error correcting features which assist the user in their operation. Also, results of analyses may be obtained instantaneously, being printed out at the terminal, and modified analyses may be easily submitted upon review of an earlier printout.

b. Prescriptive vs. descriptive models

If a computer-based model is designed to evaluate a police field operations plan without suggesting any alternate improved plans, it is said to be "descriptive" (i.e., it describes the field performance characteristics which can be expected from use of the plan). If, however, the model is designed to find improved resource allocations it is called "prescriptive" (i.e., it prescribes alternate plans which should result in improved field performance.)

c. Types of field operations models now available

Reference 13 presents a comprehensive review of the types of computer-based police field operations models which have been developed. Those most relevant to learning to use the hypercube programs are:[13]

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

o <u>District design models</u>. These analytical models are used for evaluating alternate district boundaries, car assignments to districts, and dispatching policies. They are most readily used when the number of patrol units to be fielded for each day of the week, region, and shift have already been determined by some other method, but it is also possible to use them as patrol car allocation models. (The hypercube model is the only well-documented, generally available model of this type.)

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

II. General Principles of Police Patrol Allocation

1. Introduction

Although the analytical models upon which the hypercube computer programs and the other field operations models are based are quite complex, there are a number of useful, general principles of police patrol allocation which can be understood without having to understand very much about these models. Any police planner who understands these principles will find use of the computer-based models simplified, and will also be able to check some of their results himself to verify the correctness of his input data. The following sections, adapted from reference 11, outline these principles.

2. Average Number of Units Busy Handling Calls for Service

$$= \begin{bmatrix} \text{AVERAGE NUMBER} \\ \text{OF CALLS} \\ \text{PER HOUR} \end{bmatrix} \times \begin{bmatrix} \text{AVERAGE} \\ \text{UNIT-HOURS} \\ \text{PER CALL} \end{bmatrix}$$

- example:

  2 calls per hour, average
  1 car handles each
  Average length of time to handle call, 30 minutes
  On the average, 1 car is busy
  If 2 cars on duty each is busy ½ the time
  If 4 cars on duty, each is busy ¼ the time

- Number of units on duty must at least equal average number busy

3. <u>Emergencies Do Not Occur At Orderly Predictable Times And Service Times Are Not the Same For All Calls</u>

o example:

-- calls occur exactly on the hour and half-hour - every call takes exactly 30 minutes

1 car can handle--nobody waits
--but car is always busy

-- <u>but</u>, when <u>average</u> number of calls is 2 per hour

14% of hours have no calls

27% of hours have 1 call

27% of hours have 2 calls

18% of hours have 3 calls

9% of hours have 4 calls

4% of hours have 5 calls

1% of hours have 6 or more calls

-- considering the usual spread of service times around 30 minutes

with 1 car on duty, every caller waits

with 2 cars on duty,
1/3 of calls wait
1/3 of time no car is on patrol
<u>average</u> wait until a car can be dispatched is 10 minutes (including no wait)
17% of callers wait more than 20 minutes

o <u>conclusion</u>: Number of units on duty must be considerably more than average number busy

4. <u>A Minimal Standard for Adequate Performance Is That No More Than 15 Percent of Calls are Queued</u>

o many departments don't achieve this (especially during peak hours)

o a goal set by some departments is: No more than 5% of important calls are queued

o a few departments routinely have less than 1% of important calls queued

- o impossible to guarantee that no calls will be queued

5. Cars Are Unavailable for Dispatch for Reasons Other Than Response to Previous Calls

- o what are these activities?

  meals, personal

  patrol-initiated crime or vehicle check

  notifications, warrants

  process arrestee

  supervision - field

  supervision - station

  waiting

  travel to assigned beat

  transport (something)

  assigned to fixed location

  maintenance, auto

- o ordinarily, at least 30 percent of each unit's time spent on such unavailabilities

- o in San Fernando Valley area of Los Angeles, average unavailabilities vary among divisions from 44% to 62% of total time on duty. In one New York precinct, 58 percent

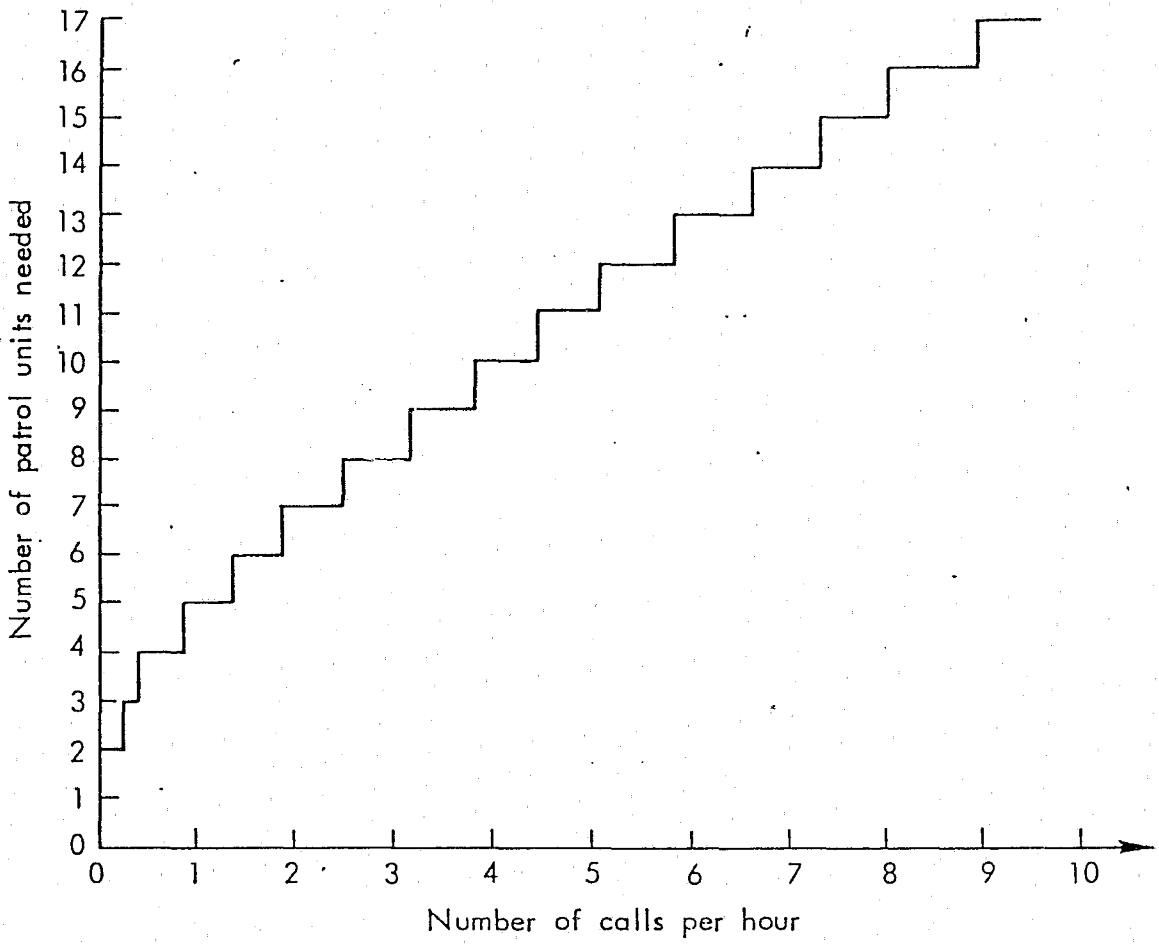
- o for queuing purposes, effective number of units on duty may be less than half the number assigned

6. Number of Units Needed to Meet Desired Level of Queuing Does Not Increase Proprotionately With Number of Calls

- o when the number of calls per hour is doubled, the number of cars needed is less than double (for the same proportion of queuing) -- see Figure II-1.

- o example

  A region with 2 calls per hour needs 7 units. This is not twice the number needed in a region with 1 call per hour (namely, 5 units) -- see Figure II-1.



Assumptions: 30 minute service time per call
50% of each car's time spent
unavailable for reasons other than dispatch to a call

Figure II-1

NUMBER OF PATROL UNITS NEEDED SO THAT AT MOST 10% OF CALLS ARE DELAYED

7. Average Number of Minutes Between Passings of A Random Point By A Unit on Patrol

- is approximately equal to

$$6 \times \frac{\text{NUMBER OF STREET MILES IN BEAT}}{\text{FRACTION OF TIME AVAILABLE}}$$

- used as a measure of amount of preventive patrol or routine surveillance

- incorporates results of studies of average patrol speeds and average number of street miles per square mile of patrol area

8. Approximate Formula For Average Travel Time

- formula

$$2 \text{ min} \sqrt{\frac{\text{AREA (in square miles)}}{\text{NO. UNITS AVAILABLE}}}$$

- example:

  area of region is 6 square miles
  5 patrol cars on duty
  each available 60% of time

  average travel time = $2 \text{ min} \sqrt{6/3} = 2.83 \text{ min}$

- why this is a general principle

- total response time =

    (dispatching delay)
  \+ (queuing delay)
  \+ (travel time)

- reducing response time is often assumed to increase probability of apprehending offender at the scene, but the effect is important only if very short response times can be achieved (and no conclusive evidence yet exists)

- reducing travel time can help to reduce response time into the useful range if queuing delays are short. It makes no sense to reduce travel times when queuing delays are long.

9. Burden of Central Location

- used in estimating each patrol car's workload of called-for-service assignments

- if the numbers of hours of work required to handle the calls arriving in all districts are equal, then cars assigned to centrally located districts will have higher workloads than those assigned to peripheral districts

10. Cross-District Dispatching

- o police administrators often prefer patrol units to handle calls in their own districts as much as possible

- o unless all incoming calls in each district are queued until the district car becomes available, it is not possible to eliminate cross-beat dispatching entirely

- o the fraction of calls for service which are assigned to cars from a district other than that in which the call originated is approximately equal to

  -- (if the average car workload is low) the average car workload, expressed as the fraction of time spent handling calls

  -- (if the average car workload is high) one minus one divided by the number of patrol cars (i.e., 1-1/N)

  -- (if the average car workload is intermediate) a value between the two given above

III. Introduction to the Hypercube Queuing Model and Computer Programs

1. Basic Features of the Model and Programs

- mainly used for district design, but can also be used as a patrol car allocation model

- types of questions which can be answered

  - -- is one set of district boundaries better than another (see Figures III-1 and III-2)?

  - -- what improvements can be expected from automatic vehicle location equipment?

  - -- how do alternate dispatching policies affect field operations?

  - -- how will the distribution of preventive patrol effort be affected by car deployment changes?

- field performance measures estimated

  - -- workloads (by region, district, car, reporting area)

  - -- travel times (by region, district, car, reporting area)

  - -- cross-district dispatching (by region, district, car, reporting area)

  - -- preventive patrol passings (by region, reporting area)

  - -- probability of queuing for incoming calls (saturation)

- types of input data required

  - -- geographic (reporting area locations, areas)
  - -- called-for-service activity (volume, distribution by reporting area, service time)

  - -- non-called-for service activity (per car)

  - -- travel speeds (call response, patrol)

  - -- dispatch policies (queue discipline, car assignments to reporting areas, dispatchers' rules, multiple car dispatching)

  - -- preventive patrol effort (distribution by reporting area)

PLAN "A"

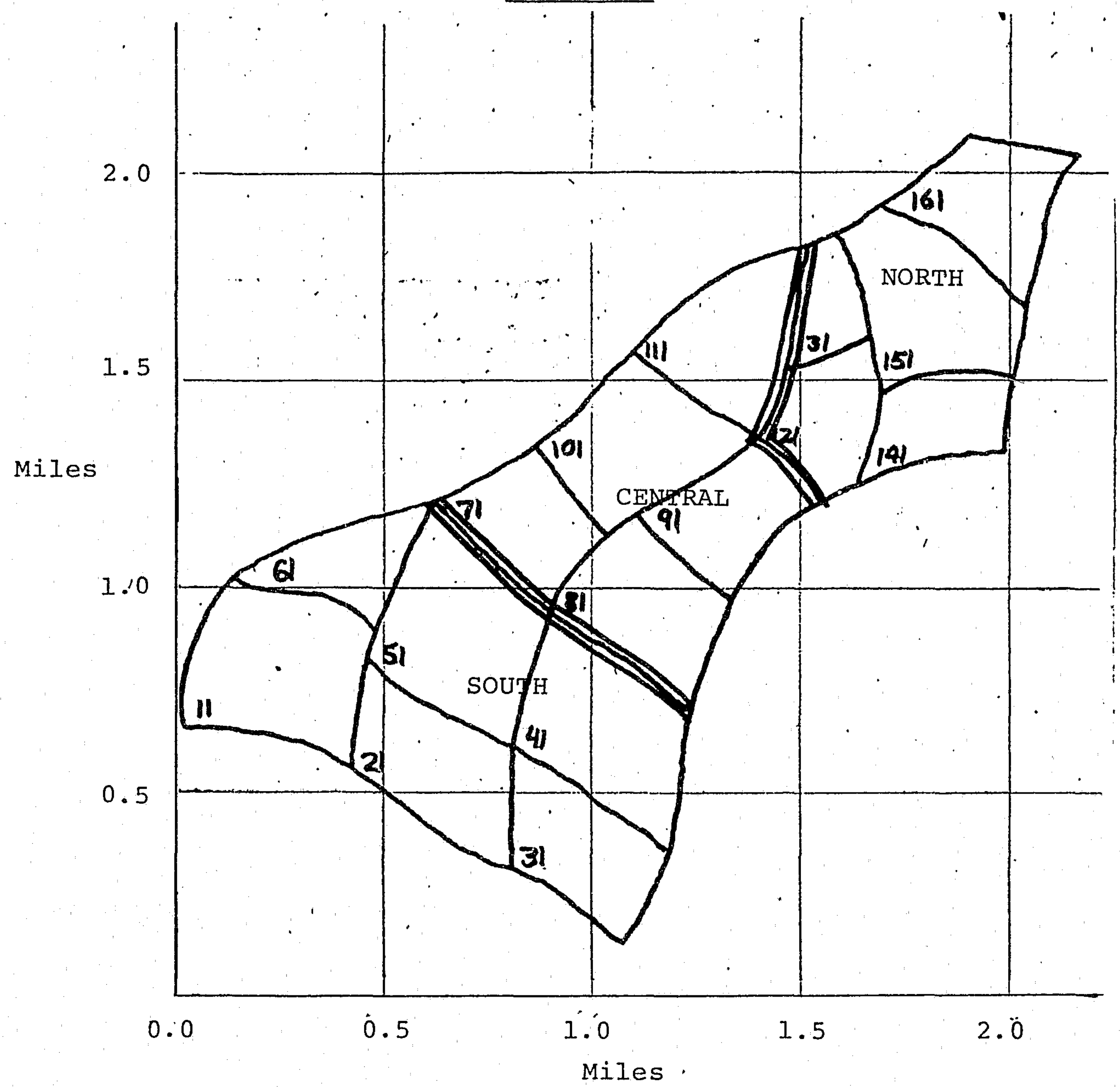


Figure III-1

MAP OF SAMPLE JURISDICTION

PLAN "B"

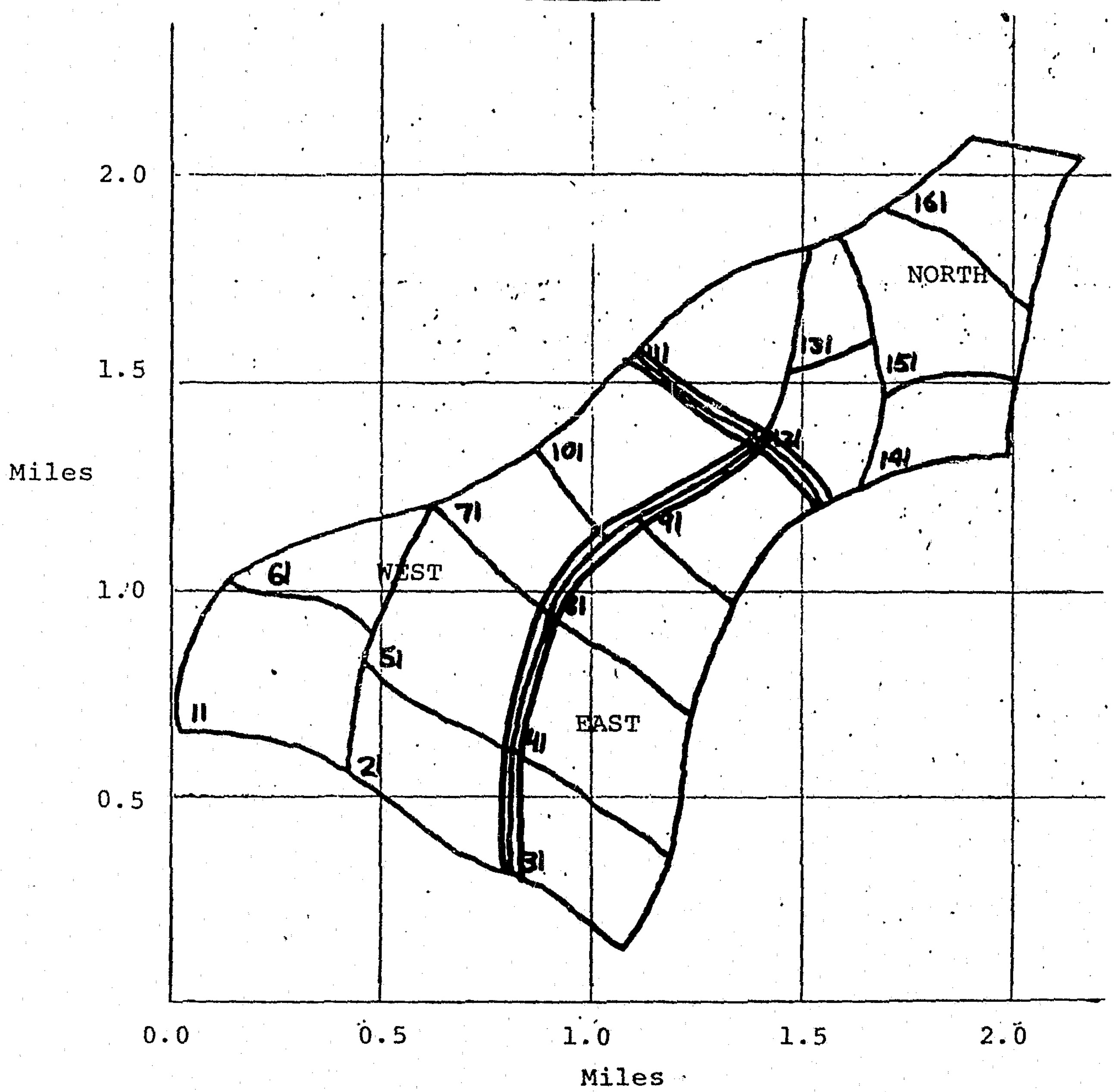


Figure III-2

MAP OF SAMPLE JURISDICTION

-- local terminology for region, district, car, reporting area

-- type of output required

o interactive (conversational, tutorial, error correcting) and batch versions of computer programs are available

o descriptive model

2. <u>What the Hypercube Computer Programs Are Not</u>

o prescriptive

o management information system

o real time inquiry system like NCIC

o computer assisted dispatching system

o automatic vehicle location system

o day-to-day planning or evaluation tool

o other resource allocation planning tools (e.g., patrol car allocation models, patrol simulation models, work schedule design models)

3. <u>History of Development of Hypercube</u>

o doctoral dissertation of Dr. Richard Larson (Massachusetts Institute of Technology)

o additional research at M.I.T. and New York City Rand Institute, funded by National Science Foundation, Dept. of Housing and Urban Development

o use of intermediate versions of programs

-- Arlington, Quincy - Massachusetts
-- New York City PD
-- New Haven - Connecticut
-- National Research Council - Canadian Police
-- Rotterdam PD - Netherlands
-- Arlington, Garland - Texas

o field test program conducted by The Institute for Public Program Analysis

-- see Table III-1

-- studied accuracy, costs, technical assistance needs

Table III-1

POLICE DEPARTMENTS PARTICIPATING
IN THE HYPERCUBE FIELD TEST PROGRAM

Department	Population of Jurisdiction	Size of Jurisdiction (Square Miles)	Number of Beats	Number of Statistical Reporting Areas
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
Saint Louis County (Mo.) (unincorporated areas)	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

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San Jose	547,500	147.4	40	-
Santa Ana	174,800	27.6	8	127

4. <u>Advantages of Use of Hypercube Programs</u>

- o easy to use - interactive version provides tutorial assistance for the novice user; data processing experience is not a prerequisite for using the programs
- o built-in error checking features (interactive version only) - data and command errors are revealed as soon as they are input
- o allows changes in the performance measures to be estimated without actual changes in patrol operations - avoids costly and disruptive field experimentation
- o unnecessary to own either a computer or the programs (interactive version only)
- o (efficient) use can reduce planning costs
- o automates all the calculations used in manual district design methods
- o powerful training tool for learning how to plan field operations
- o aids in creating a continuing data base for field operations planning, evaluation
- o allows incorporation of constraints and objectives not explicitly included in the model; uses expertise of police planner to suggest alternatives

5. <u>Costs/Disadvantages of Use of Hypercube Programs</u>

- o requires commitment of chief and others to support planning effort through field implementation
- o data collection is sometimes costly and time consuming; some data may not be available
- o results may be rejected by field operations personnel because they're computer-based or ignore important considerations
- o if the batch version is used, it lacks the conversational, tutorial, and error correcting features of the interactive version
- o use of the interactive version requires a budget for commercial time-share data processing service (can't be done on most PD's computers)
- o data processing costs can be high, especially if used carelessly

- requires investment in training the program user, which may be lost if he is transferred or leaves PD

- changes in patrol district boundaries may require costly changes in other police operations (e.g., communications, computer assisted dispatching systems, records)

- most departments will use hypercube infrequently (e.g., every 6 months to a year)

- technical assistance in use of the programs may not be free, if needed

6. <u>Criteria By Which District Plans Are Judged and Compared</u>

Chapter I included a discussion of the criteria used in assessing patrol allocations. In this section, the criteria specifically used in assessing district plans are identified. The relative importance of these criteria varies among police departments, and is dependent upon local policies and concerns. Also, some objectives may conflict with other objectives (i.e., the optimization of one performance measure may cause a degradation in one or more other measures). As a result, an important, preliminary step in district design (or redesign) is the specification of an acceptable level of each performance measure and identification of the "most important" characteristic of a district plan from among the following attributes:

- <u>workload balance</u> - the equalization over the patrol units of the work performed by each unit. A variety of workload measures have been used for district plans including: the number of major crimes handled by each unit, the total number of calls responded to by each unit, and the total amount of time spent in answering calls by each unit. (This last measure is used by the hypercube programs.) Equalization of time worked by patrol units in handling calls for service further implies that the amount of time available for activities other than calls for service (e.g., preventive patrol, conducting patrol-initiated investigations, or interacting with the community) is also balanced.

- <u>accessibility to police service</u> - the equalization, to the extent permitted by geographic factors, of average travel time to incidents in all areas of the jurisdiction. This requires accounting for natural barriers to travel such as rivers, canyons, and freeways.

- minimization of the number of cross-district dispatches-preserving each officer's district identity, and taking fullest advantage of his knowledge about the people and problems in his district.

- minimization of response time - the length of time a citizen initiating a call for service has to wait before a patrol unit arrives, due to any temporary unavailability of units and to travel time. (Hypercube does not compute the total response time, only the travel time, but a simple manual calculation with other hypercube output yields response time.)

- officer safety considerations - deploying patrol units in such a way that any car can receive prompt assistance from other cars in an emergency.

- extra coverage of "hot spots" - placement of district boundaries so that they pass through locations having a history of a high volume of crimes and calls for service, assuming that these areas will then be patrolled by more than one patrol unit.

- political impact - assessment of the reception likely to be given to a district plan by influential individuals and groups, both within the police department and the community.

- span of supervision - the extent to which patrol sergeants will be able to observe, assist, or conveniently deploy patrol units under their command.

- preservation of neighborhood integrity - avoiding the splitting of a homogeneous neighborhood between two or more districts.

- minimization of change from an existing district plan - reduces the time required by officers and dispatchers to familiarize themselves with a new plan, reduces the effort required to update an existing computer-aided dispatching system (if one is in use), and reduces the impact on other police operations whose deployment plans are based on the existing beat plan (e.g., tactical units, ambulance service, detective operations, communications, records)

- use of main streets and natural barriers as district boundaries

7. Assumptions On Which the Hypercube Programs Are Based

In order to model the very complex operations involved in police patrol and response to calls for service, the designers of the hypercube programs chose to make a number of simplifying assumptions. Users of the programs should be aware of these assumptions and of their impact on the patrol performance factors estimated by the programs. Many of these assumptions are not unique to the hypercube programs, having been used in other police operations analyses to reduce their mathematical procedures to managable dimensions. Available experimental evidence tends to indicate that these assumptions are generally reasonable, but corrective procedures may be needed in situations where actual operations differ considerably from the assumed circumstances. The following paragraphs discuss the most important of these assumptions and situations in which corrective procedures may be needed.

a. Occurrence of calls for service

- assumptions

  (1) Arrival of calls is random.
  (2) Average number of calls originating in any district during a watch can be reliably predicted using historical data.
  (3) The time intervals between the arrivals of consecutive calls, although random, can be accounted for mathematically using probability theory.
  (4) The variation in number of calls arriving per hour in any beat is described by the Poisson distribution (see Figure III-3).

- problem situations

  (1) Some unusual events, like storms, can cause significant increases in the numbers of calls received during a watch.

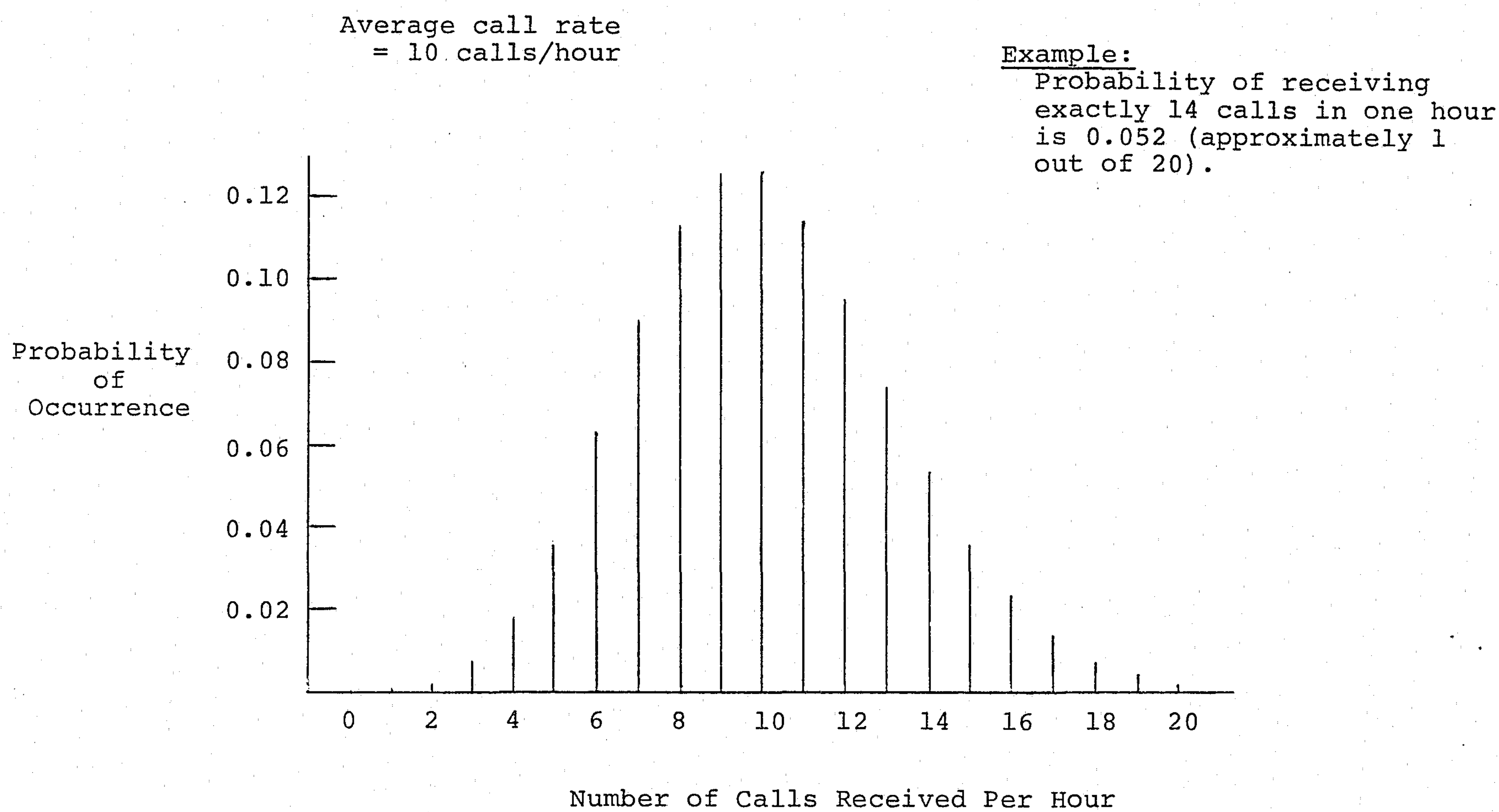

Figure III-3

VARIATIONS IN THE TOTAL NUMBER OF CALLS FOR SERVICE RECEIVED IN ONE HOUR BASED ON A POISSON DISTRIBUTION WITH AN AVERAGE RATE OF 10 CALLS PER HOUR

(2) Some calls for service occur regularly, not randomly. Some police departments treat school crossing duties as calls for service.

b. Officer-initiated and administrative work

o assumptions

(1) Occurrence is random.
(2) Incidents can be modelled in the same way as calls for service.
(3) Workload for officer-initiated and administrative work should be added to that of called-for-services.

o problem situations

(1) The volume of officer-initiated and administrative work may depend on the volume of called for service work(e.g., as called for service work increases non-called-for-service work decreases).
(2) Officer-initiated and administrative work may not be distributed geographically in the same way as calls for service.
(3) Some of this work occurs at scheduled intervals, not at random (e.g., school crossing coverage).

c. Time required to service a call

o assumptions

(1) Service time includes travel time and time at the scene.
(2) Travel time accounts for a small portion of service time.
(3) Service times are random and are described by the negative exponential probability distribution (see Figure III-4).
(4) Average service times may be predicted from historical data.
(5) Average service times may vary from car to car, but (strictly speaking) not from district to district.

o problem situations

(1) Service times for consecutive dispatches may be related, not random (e.g., if the second is an assist car for the first).
(2) Average service times may vary among reporting areas due to differences in the types of calls received.
(3) For large rural or semi-rural beats travel time may not be a small part of service time.
(4) Service times for officer-initiated and administrative work may depend on the called-for-service volume.

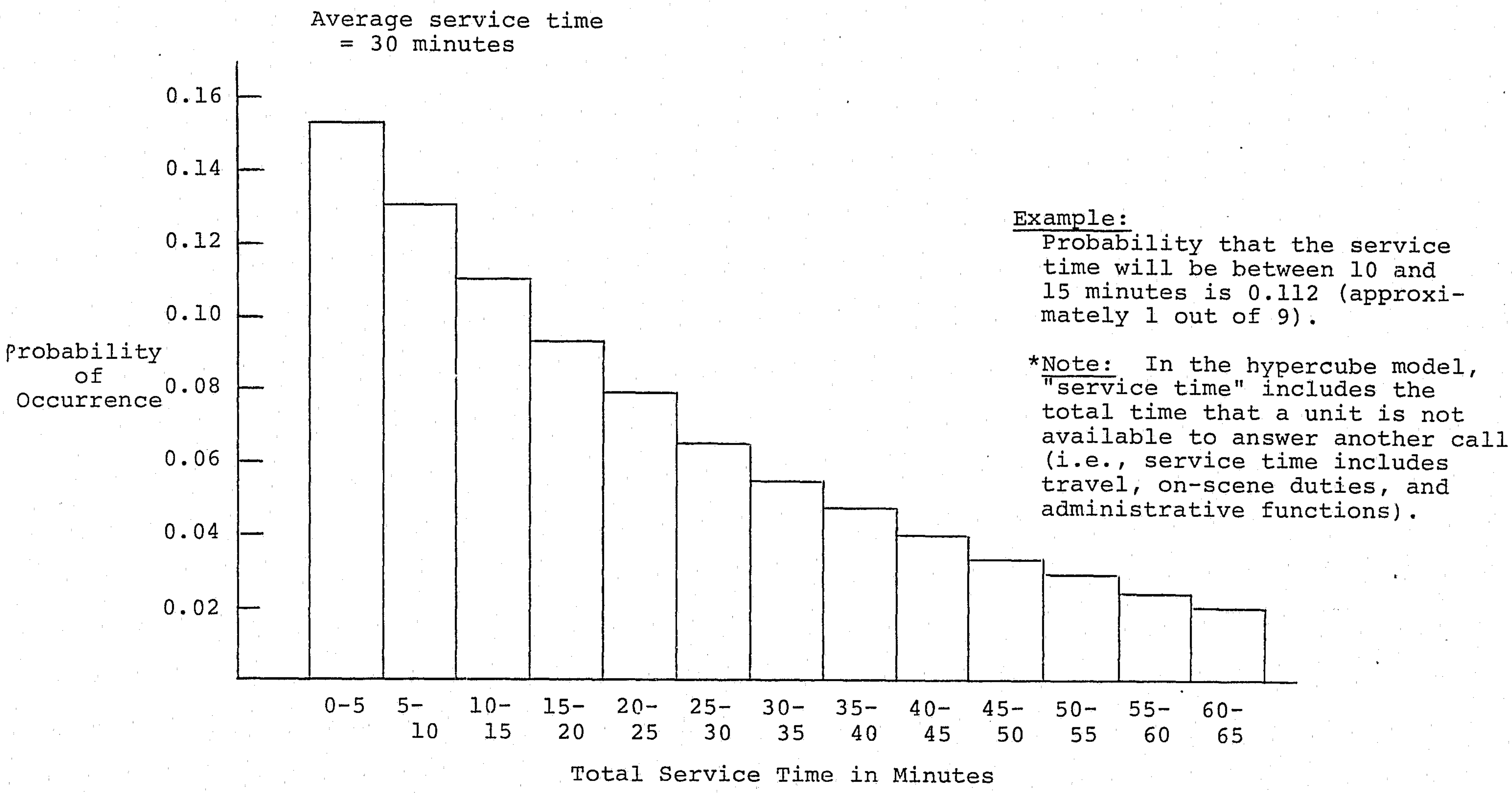

Figure III-4

VARIATIONS IN THE TOTAL SERVICE TIME* BASED ON A NEGATIVE EXPONENTIAL DISTRIBUTION WITH AN AVERAGE SERVICE TIME OF 30 MINUTES

d. Dispatch policy (assignment of calls to cars)

- assumptions

(1) Strictly speaking only one patrol unit is dispatched to any call for service (multiple dispatches occur sufficiently infrequently to be ignored).
(2) Calls for service received when all units in a district are unavailable are either queued by the dispatcher, or assigned to a "backup unit" (e.g., sergeant, canine) not explicitly represented in the model.
(3) Cars are never reassigned to another (perhaps more serious) call once given a first assignment (i.e., not until the first assignment is completed).
(4) Queued calls are serviced on a first-in, first-out basis, regardless of the relative priorities of the calls.
(5) Dispatches taking a car across a region boundary occur sufficiently infrequently to be ignored.
(6) The procedures used by dispatchers to assign incoming calls to cars are the same for all dispatchers. The assignments depend mainly on how well the dispatchers know the locations of the incidents and the locations of the available cars. For the interactive version of the programs, one of five available dispatch policies will be a good model for any police department (other policies cannot be substituted). Some special rules are, however, allowed.
(7) Time spent in processing incoming calls for service at headquarters, by telephone operators, or by dispatchers prior to attempting to locate an available car, is insignificant compared to call service time.
(8) Only cars dispatched to an incident will respond to that incident.

- problem situations

(1) Department policy may require the dispatching of of more than one car to some types of incidents. These incidents may occur frequently enough to warrant inclusion in the analysis.
(2) Cars may sometimes be preempted from a low priority assignment.
(3) Queued calls for service may be dispatched on a priority basis, higher priority calls being dispatched before lower priority calls.
(4) Cross region dispatches may not be infrequent.

(5) Dispatchers may vary in their procedures for assigning calls to cars, and may not follow any of the five policies available in the interactive program.
(6) Time spent processing calls at headquarters may be considerable.
(7) Available patrol cars not assigned to an incident may decide to respond to ("roll by") the incident.

e. Travel time and travel distance

o assumptions

(1) Travel speed can be approximated by two values -- one for response to calls for service, and the other for preventive patrol.
(2) Travel distances between reporting areas are calculated using the "Manhattan metric" assuming a grid of rectangular city blocks (see Figure III-5).
(3) The travel distance for a car responding to a call in the reporting area it is patrolling is calculated using the formula $\text{distance} = C\sqrt{\text{size (in square miles) of reporting area}}$ where C is a constant of proportionality.
(4) The average travel distance (or time) for a car assigned to a given district responding to specified reporting area depends on the preventive patrol policy in use, and is estimated using a formula based on the Manhattan metric.
(5) When a patrol unit is not assigned to a call for service it patrols among the reporting areas in its district. The fraction of time spent in each reporting area is dependent on either the called-for-service workloads in the reporting areas, or on the preventive patrol factors assigned to the reporting areas.

o problem situations

(1) Travel speed may vary with traffic conditions and with the urgency of the call.
(2) The Manhattan metric may not be an adequate formula for estimating travel distances between reporting areas. For example, the streets may cross at angles that are not right angles. Also, barriers such as freeways, rivers, or canyons, may significantly increase travel distances between some points.
(3) None of the formulas for travel distances associated with the five alternate dispatch policies available in the interactive program may be accurate.
(4) Cars not assigned to a call for service may not patrol their districts in the manner assumed (e.g., they may visit another district or be asked to meet with their sergeant).

distance between reporting areas a and b

$$= X+Y = |x_b - x_a| + |y_b - y_a|$$

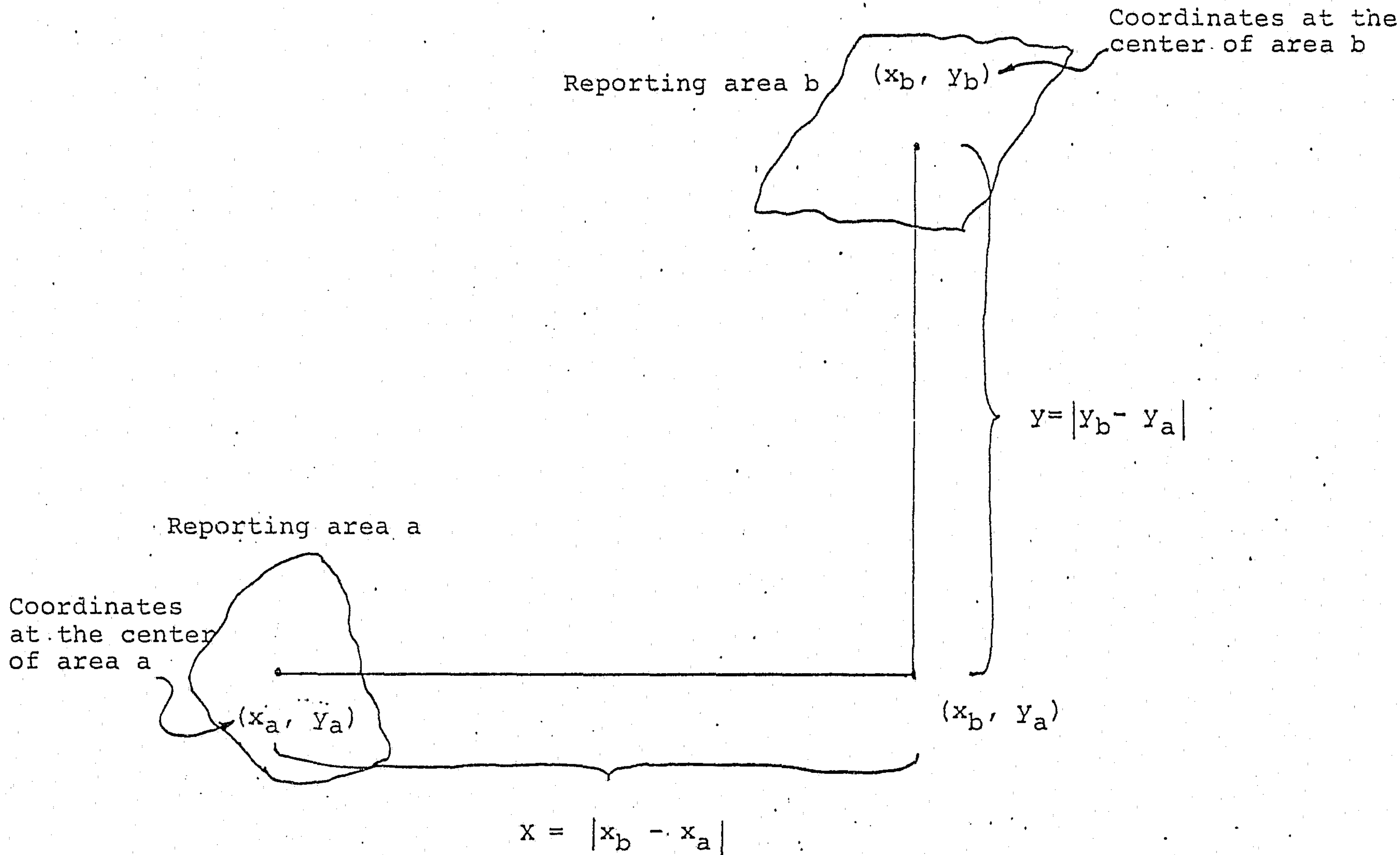

Figure III-5

MANHATTAN METRIC METHOD OF DISTANCE MEASUREMENT does not accept a grounded plug, an adapter will also be necessary).

b. Prior to telephoning the computer, check the paper supply in the terminal, connect the terminal to the electrical outlet, and turn on the terminal's power switch.

c. Control switches and/or keys on the terminal should be set as follows:

- o Parity - if the terminal has a parity switch, it should be set to "EVEN".
- o Duplex - terminals with a switch should be set to "HALF"; on terminals with a "HALF DUP" key, this key should be in its depressed position.
- o Operating speed - teletypewriter terminals can often be operated at a user-selectable speed of 10, 15, or 30 characters per second*; the operating speed is specified by setting a switch on some terminals, or by placing a "LOW SPEED" key in its depressed (10 CPS) or non-depressed (30CPS) position.
- o Operating mode - teletypewriter terminals can also be operated "on line" or in "local" mode; in order to access a time-share system, the terminal should be "on line"; to specify this operating mode, set the mode switch to "LINE", or place the "ON LINE" key in its depressed position, depending on the type of terminal being used.
- o Interface - if the terminal being used has an internal acoustic coupler and an interface switch, this switch should be set to "INT."

2. <u>Accessing the NCSS Data Processing System</u>

a. <u>Information required</u>

Information required to access the NCSS system includes the following:

- o A one to eight character user identifier, referred to as the "userid" in the following discussion.

---

*Higher-operating speeds correspond to faster printing of data transmitted from the computer to the terminal, and to higher hourly connect charges.

- o A one to eight character password used to prevent unauthorized use of a user's account and access to his data files.

- o The telephone number of the nearest NCSS access point.

These items are obtained from NCSS administrative personnel when an account is established on the NCSS system. (See the report "How to Set-up Shop for Use of the Hypercube System" for a discussion of how to arrange for data processing services and equipment.) Both the userid and password should be treated as confidential information. Telephone numbers for accessing the NCSS system from other locations can be obtained by logging on and typing

INFO PHONLIST location

where "location" is the city or state for which you want a listing of telephone numbers. For reference, the telephone number of NCSS's national business office is 203-853-7200; users who require information on access points, and cannot conveniently obtain it by logging on to the system should phone the business office.

b. <u>Operating conventions during terminal sessions</u>

The following general conventions apply to operations involving the use of a teletypewriter terminal to communicate with the NCSS system:

(1) All communications from the NCSS computer to the terminal are printed using uppercase alphabetic characters. Communications from the terminal to the NCSS computer can use either uppercase or lowercase alphabetic characters (or both), unless the terminal employed does not provide this capability, in which case only uppercase letters are used. Sample terminal sessions in this report always use lowercase characters to represent user input typed at the terminal.*

(2) Whenever a ">" is printed on the terminal, the computer is waiting for additional user input. If the ">" is preceded by the time-of-day, the computer expects the user to enter an NCSS/hypercube command (see Table D-1). Otherwise, it is waiting for the user to enter data or respond to its previous question.

---

*Note that a slightly different convention is used throughout the text. Specifically, uppercase characters are used to represent system responses or user input that must be typed exactly as shown. Lowercase characters are used to represent generic names for which the user can substitute other names.

(3) The letters "Y" and "N" are acceptable abbreviations for "YES" and "NO".

(4) Commands and data typed at the terminal are transmitted to the computer only when the "RETURN" key (the "CR" key on some terminals) is depressed. Therefore, each line of input to the computer should be followed by a carriage return, even if this operation is not explicitly stated in the instructions in this and following chapters.

(5) Since user input is not transmitted until the "RETURN" key is depressed, typing errors can be corrected. The "@" key is used to delete the last character typed. Multiple characters are deleted by depressing the "@" key the appropriate number of times. The "¢" key (or the "[" key on some terminals) is used to delete the entire line. Characters or lines entered prior to the last time the "RETURN" key was depressed cannot be deleted.

(6) During some operations (e.g., program execution), a "$" is printed for every four ARU's of computer usage (i.e., after approximately $0.80 of processing).

(7) The execution of a previously entered command can be terminated using the following procedure:

(a) Depress the "BREAK" key

(b) The computer should respond

```
VP

>
```

In reply, depress the "BREAK" key a second time.

(c) The computer should respond

```
>
```

In reply, key in

```
KL
```

(d) The computer should respond

```
KILLED!
CSS.301  10/23/76
time-of-day>
```

(e) At this point, execution of the previous command has been terminated, and any new command can be entered.

c. Logging on to the NCSS system

The following procedure is used to log-on the NCSS system:

(1) Dial the telephone number of the nearest access point.

(2) When you hear the high pitched tone, place the telephone handset in the receptacles at the rear of the terminal, with the earpiece in the right most receptacle. The word "cord" appears on some terminals adjacent to the receptacle which receives the handset mouthpiece, since the telephone cord is at this end of the handset. (On some terminals, the two receptacles are on the lefthand side. For these models, the telephone earpiece should be placed in the rear receptacle.) At this point, the "ready" light on the front of the terminal should be illuminated.

(3) Key in the speed identification character which corresponds to the terminal operating speed that you have selected, and depress the "RETURN" key. Speed identification characters are shown in Figure IV-1.

(4) At this point, the computer should respond

```
CSS ONLINE -

>
```

In reply, key in

```
LINK M168 userid
```

Operating Speed (Characters Per Second)	Speed Identification Character	Hourly Connect Charge*
10	S	$10.00
15	Y	$10.00
30	O	$13.00

*Rates in effect in January 1977

Figure IV-1

TERMINAL OPERATING SPEEDS

(5) At this point, the computer should respond

PASSWORD:
[redacted]

In reply, key in your password.

(6) At this point, the computer should respond

A/C INFO:

>

In reply, key in up to 16 non-blank characters of account information in two eight character fields separated by a blank. This information can be used to provide a separate accounting of data processing charges for separate tasks, since the NCSS invoices provide a breakdown of charges for each unique identifier specified as "A/C INFO" during the billing period.

(7) At this point, the computer should respond by printing

system messages
M168 READY AT time-of-day ON date
CSS.301 10/23/76
time-of-day >

(8) At this point, the process of logging-on is complete, and any NCSS/hypercube command may be entered. (See Figure E-1 for a guide to the operations that can be performed at this point.)

d. <u>Logging-off of the NCSS system</u>

The following procedure is used to log-off of the NCSS system:

(1) After the computer has printed

time-of-day >

key in

LOGOFF

(2) The computer should respond

xx.xx ARU's, x.xx CONNECT HRS
LOGGED OFF AT time-of-day ON date

and the "ready" light on the terminal should go out.

(3) At this point, the telephone can be disconnected from the terminal. Approximate session charges can be computed by multiplying the number of ARU's by $0.20, the connect hours by the hourly connect charge corresponding to the operating speed being used (see Figure IV-1), and summing the results. (Rates given were those in effect in January 1977.)

Figure IV-2 contains a sample terminal session in which a user with userid "HERCULES" logs on and off the NCSS system using a terminal with an operating speed of 30 characters per second. Approximate session charges are

$$(0.2)x(2.42) + (13.00)x(.01) = \$0.62$$

Figure IV-3 contains a sample log for recording computer usage.

e. Dealing with routine problems

Following is a partial list of problems that may occur during terminal sessions, and procedures that should be followed when these problems arise:

(1) Logging on

(a) Telephone access number busy - Occasionally, a "busy signal" is received when the NCSS access number is dialed. This indicates that all telephone lines into the computer are currently in use. This is most likely to occur during mid-morning or mid-afternoon when system usage is heaviest.

When this occurs, dial an alternate access number if there is one for your location, or else hang up and wait several minutes before redialing.

(b) NCSS system "down" - Periodically, the NCSS system may be unavailable because of equipment failure, or because the system has been shut down for the day. (This latter condition is rare, however, since the current (January 1977) schedule calls for system operations at all times except 4:00 a.m. - 5:00 a.m., Eastern time, daily.) Depending on your location, this may cause the computer to not answer when the NCSS access number is dialed, or to respond

```
M168 UNAVAILABLE
LINK
>
```

after the LINK command has been entered. In either case, hang up and wait several minutes before redialing.

```
□

CSS ONLINE - CHI1

>LINK M168 HERCULES
PASSWORD:
BBBBBBBB
A/C INFO:
>SAMPLE SESSION
M168 READY AT 17.52.42 ON 08NOV76
CSS.301 23OCT76

17.52.49 >LOGOFF

2.42 ARU'S, .01 CONNECT HRS
LOGGED OFF AT 17.53.03 ON 08NOV76
```

Figure IV-2

LOGGING-ON AND OFF THE NCSS SYSTEM

DATE	LOG-ON	LOG-OFF	ACTIVITY	VPU	CONNECT HOURS	COST

Figure IV-3

SAMPLE LOG FOR RECORDING COMPUTER USAGE

(c) Entering the "LINK" command during the log-on process
If an error is made while keying in the "LINK" command when logging-on, the computer may respond

```
HOST NOT VALID
LINK
>
```

or

```
INVALID ID
LINK
CSS ONLINE -
>
```

depending on the error made. When this occurs, reenter the entire "LINK" command.

(d) Entering your password - If an error is made in entering the password, the computer will respond

```
PASSWORD INCORRECT
PASSWORD:
```

When this occurs, reenter the password. If an error is made in reentering the password, the computer will respond

```
LOGGED OFF AT time-of-day ON date
```

and the telephone line will be disconnected. When this occurs, the entire log-on process must be repeated.

(2) During a terminal session

(a) Disconnected communication line - When terminal operations are interrupted by a disconnected telephone line, the user is not automatically logged-off the system for 10 minutes. This is significant for two reasons. First, the user is charged for the additional 10 minutes of connect time. More importantly, the interrupted activity can be resumed if the user reconnects his terminal to the NCSS system within 10 minutes; otherwise, the results of the interrupted operation are lost. The following procedure is used to reconnect to the system:

(i) Repeat the logging-on process.

(ii) The computer should respond

```
USER ON BUT DISCONNECTED
HIT RETURN OR ENTER 'CONNECT' OR 'KILL'
>
```

(iii) In reply, key in

CONNECT

to resume previous operation, or

KILL

to terminate the previous operation.

(b) NCSS system failure - if the computer goes down in the middle of an operation, the results of all activities since the last time the computer printed the time-of-day are lost and cannot be recovered. This condition is distinguished from a communication failure in that one of the computer responses described in (1)(b) above will result when you attempt to reconnect.

V. Input Data

1. Data Requirements

In order to use the hypercube programs to design police patrol beats (referred to as "districts" in the remainder of this report) three types of input data are specified: geographic/call volume data describing the jurisdiction of interest (referred to below as a "region"), data describing the various important features of patrol operations (termed the "district plan") in the region, and supplementary items used to modify other input data, as well as hypercube output. Each type of data can be further categorized as "required" or "optional." Required data must be measured or estimated by the user, and supplied to the programs in an appropriate format. (Data input is discussed in Chapter VI.) On the other hand, the user need not provide any or all of the optional data items. In some cases, failure to specify a particular data item will mean that certain hypercube output statistics will not be calculated. In other cases, the computer will assume a value for omitted data items and calculate various performance measures as if the user had explicitly specified that value. Such assumed values are termed "defaults." Users should be aware of the hypercube defaults and assumptions being made to ensure that they are realistic in light of actual patrol operations. The various input data items are briefly discussed below. Table D-3 classifies each item according to whether it is required or optional. Units of measure, applicable defaults and assumptions, and restrictions on the data items are also summarized.

a. Geographic/call volume data

For any given beat design problem, the geographic/call volume data are independent of the particular district configuration and patrol operations specified. Consequently, they need not be modified when new beat designs are examined. Geographic/call volume data include the following:

- Reporting area - the jurisdiction of interest must be partitioned into reporting areas smaller than a district (ideally, there should be between 6 and 12 reporting areas for each district); these areas are given unique numeric identifiers. If a police department does not have reporting areas, other existing geographic systems such as census blocks or tax districts can be used.

- Location of the geographic center of each reporting area-(x,y) coordinates for each area can be measured by superimposing a rectangular coordinate system on a city map.

- Size of each reporting area in square miles - can be estimated using a system of grid lines superimposed on a city map.

- Relative volume of calls for service in each reporting area - The expected proportion of calls for service in each reporting area during the watch, days of the week, and season of year for which the new district plan will be used. Either proportions or actual numbers of calls expected can be used.

- Patrolled street miles in each reporting area - if actual data is unavailable, the number of street miles can be approximated by multiplying the size of each reporting area by 35, for most cities.

b. Data describing patrol operations, dispatch policies, district configuration, etc.

The following data items are used to describe the patrol operations in the region:

- Travel speeds - separate travel speeds can be specified for units on preventive patrol and for units responding to calls for service. In addition, separate response speeds can be specified for units travelling in the direction of the X- and Y-coordinate axes used to measure the geographic centers of reporting areas. Travel speeds can usually be estimated using data on the distance travelled and the time from dispatch to arrival. Response speeds can also be used to calibrate the model so that the hypercube program's travel time estimates agree fairly well with department estimates of the average time between the dispatch of a unit and that unit's arrival at the incident location. To use the response speed to calibrate the model to reproduce the department's estimate of region-wide travel time, the hypercube program must be run once for the current district configuration using an arbitrary response speed, say 10 m.p.h. Region-wide average travel time will be calculated as part of the program's performance statistics. If the hypercube is rerun using a response speed of

  10 x (region-wide average travel time) / (empirical average travel time)

  then the program's estimate of region-wide average travel time should agree with the department's empirical estimate of the average travel time.

- Dispatch policy - the dispatch policy is defined by specifying how accurately a dispatcher knows the location of each response unit and each call, whether the district car is preferred over a closer available unit, and whether calls are queued when no units are available. This information must be obtained by interviewing dispatchers and other field operations personnel, and by studying dispatchers' decisions when confronted with various field situations. Specification of the dispatch policy is discussed in more detail in Chapter VI.

- District configuration - a listing of the reporting areas included in each district.

- Preventive patrol factors - the relative distribution of each unit's preventive patrol time among the reporting areas in its district.

- Average service time - average amount of time required to complete a call for service, including travel time, time spent on-scene, and administrative follow-up time (e.g., report writing) in minutes. Separate service times for each unit can be specified.

- Average call for service rate (in calls/hour).
- Non-call-for-service (non-cfs) workload - the average number of minutes per hour that units spend on non-call-for-service work which makes them unavailable for dispatch to calls for service.

c. Supplementary data used to modify hypercube input and output

The following items are used by the hypercube programs to modify geographic and patrol input data, to modify the programs' output, and to perform internal calculations (e.g., travel times):

- Proportionality constant used in computing intra-reporting area travel times - see Section III.7.
- Inter-reporting area travel times - the average time required to travel between pairs of reporting areas.
- Scaling factor used to convert x,y coordinates to miles.
- Title of the district plan - a descriptive title used as heading information in the hypercube output.
- Glossary - terms to be used in hypercube output to refer to response units, districts, calls for service, reporting areas, and travel times.

2. Storage of Input Data

In time-sharing operations, data are stored in on-line disk storage units for later retrieval by both the user and by computer programs which use the data as input. Disk storage "compartments" which contain collections of data are termed "files." Hypercube input data are stored in two types of files: region files and district plan files. Region files contain the geographic and call volume data for a single jurisdiction, while district plan files contain both the data describing patrol operations and the supplementary data described above. Each file is referred to by a unique, user-defined name which can be any combination of one to eight non-blank characters. Descriptive file names which give an indication of the file's contents (e.g., "PRECNT1" for the region file for the first precinct, or "DAY1" for the district plan file for the day watch in precinct 1) are recommended. In addition, users should keep a log showing the names and contents of their files since eight character names tend to be somewhat cryptic. (See Figure D-2 for a sample file log.)

3. Format of Region and District Plan Files

a. Region files

Region files are comprised of individual lines or "records" which are 80 characters in length. The first such record contains the number, R, of reporting areas in the region, right justified in the first seven columns. This is followed by R records (one for each reporting area) which can contain a reporting area identifier (right-justified in columns 1-7), the x-coordinate of the reporting area's geographic center (right-justified in columns 8-14), it's y-coordinate (right-justified in columns 15-21), the size of the reporting area in square miles (right-justified in columns 22-28), a measure of the reporting area's relative workload (right-justified in columns 29-35), and the number of patrolled street miles in the reporting area (right justified in columns 36-42). A sample region file is shown in Figure V-1.

b. District plan files

District plan files are much less "regular" in their format than are region files. Their contents depend heavily on the features specified in the district plan. In general, the format is similar to that used for the data decks described in "Hypercube Queuing Model: User's Manual" (R-1688/2-HUD) although differences do exist. These differences are discussed in Chapter VI. A sample district plan file is shown in Figure V-2.

4. NCSS Commands Used for Managing Region and District Plan Files

This section discusses commands that can be used on the NCSS system to perform certain management functions associated

- Travel speeds - separate travel speeds can be specified for units on preventive patrol and for units responding to calls for service. In addition, separate response speeds can be specified for units travelling in the direction of the X- and Y-coordinate axes used to measure the geographic centers of reporting areas. Travel speeds can usually be estimated using data on the distance travelled and the time from dispatch to arrival. Response speeds can also be used to calibrate the model so that the hypercube program's travel time estimates agree fairly well with department estimates of the average time between the dispatch of a unit and that unit's arrival at the incident location. To use the response speed to calibrate the model to reproduce the department's estimate of region-wide travel time, the hypercube program must be run once for the current district configuration using an arbitrary response speed, say 10 m.p.h. Region-wide average travel time will be calculated as part of the program's performance statistics. If the hypercube is rerun using a response speed of

  10 x (region-wide average travel time) / (empirical average travel time)

  then the program's estimate of region-wide average travel time should agree with the department's empirical estimate of the average travel time.

- Dispatch policy - the dispatch policy is defined by specifying how accurately a dispatcher knows the location of each response unit and each call, whether the district car is preferred over a closer available unit, and whether calls are queued when no units are available. This information must be obtained by interviewing dispatchers and other field operations personnel, and by studying dispatchers' decisions when confronted with various field situations. Specification of the dispatch policy is discussed in more detail in Chapter VI.

- District configuration - a listing of the reporting areas included in each district.

- Preventive patrol factors - the relative distribution of each unit's preventive patrol time among the reporting areas in its district.

- Average service time - average amount of time required to complete a call for service, including travel time, time spent on-scene, and administrative follow-up time (e.g., report writing) in minutes. Separate service times for each unit can be specified.

```
11.45.40 >PRINTF REGION1 DATA

  16
  11     2.5    6.0    13    15
  21     6.0    3.6    10    12
  31     9.5    1.5     9     7
  41     9.8    4.6    11     8
  51     6.5    6.8    13    10
  61     4.0    8.2     6     8
  71     8.0    9.0     7     8
  81    10.6    7.1    10     6
  91    12.9    9.5     7     3
 101    10.5   11.2    12     5
 111    12.3   13.4    10     3
 121    14.6   11.6     7     2
 131    14.6   14.1     4     1
 141    17.1   11.8     6     2
 151    17.0   14.3    12     5
 161    18.1   16.8     6    10
```

Figure V-1

SAMPLE REGION FILE

```
11.35.25 >PRINTF REG1PLAN DATA


M =   3     R = 16     NUM = 1     ESTSTAT = 1      ;
'GLOSSARY'
R+DIST = 'BEAT     '
ATOM = 'RPT AREA'
R+UNIT = 'BEAT PATROL CAR     '
T+COST = 'TRAVEL TIME         '
CFS = 'CALLS FOR SERVICE '
NM+UNIT(  1) = 'BEAT CAR'
NM+UNIT(  2) = 'BEAT CAR'
NM+UNIT(  3) = 'BEAT CAR'
NM+DIST(  1) = 'BEAT     '
NM+DIST(  2) = 'BEAT     '
NM+DIST(  3) = 'BEAT     '
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'    'REGION1 - CARS IN SOUTH, CENTRAL, NORTH                  '
'NO+PRNT+AT'
'ATOM+NO'
'LAM'
'S'        1      6     11     21     31     41     51     61
'S'        2      5     71     81     91    101    111
'S'        3      5    121    131    141    151    161
'D+SCALE'   1.000
'SPEED'     15.00
'PATROL'          7.5
'TM'
'CORTM'     0.667

'NCM'
'FRST'
'CAP'
'SERVTM'      30.0

'[illegible]'   1.00     0.00
```

<u>**Figure V-2**</u>

SAMPLE DISTRICT PLAN FILE

with files. Commands for creating and modifying region and district plan files are discussed in the next chapter.

a. Listing the names of files

In order to obtain a listing of the names of your stored files, enter the command

LISTF

after the computer has printed

time-of-day>

To list only the names of region and district plan files, enter

LISTF * DATA

and to list only the names of output files (discussed in Chapter VIII), enter

LISTF * LISTING

Figure V-3 illustrates the usage of the "LISTF" command. The computer responds to the "LISTF" command by listing file names, file types (i.e., "data" for region and district plan files, and "listing" for output files), file modes ("P" for region, district plan, and output files), and the number of items (i.e., the number of 80 character records).

b. Changing the name of a file

To change the name of a region or district plan file, enter the command

ALTER oldname DATA P newname * *

To change the name of an output file, enter

ALTER oldname LISTING P newname * *

In both cases, the computer will respond by printing the time-of-day.

c. Listing the contents of a file

To list the contents of a region or district plan file, enter the command

PRINTF filename DATA

```
11.[illegible].00 >LISTF * DATA

FILENAME FILETYPE MODE    ITEMS
PR5AFT1  DATA      P       023
PRE5DAY  DATA      P       092
PRE5AFT  DATA      P       092
PRE5MID  DATA      P       092
PR5MID1  DATA      P       022
PR5DAY1  DATA      P       023
PRECNT2  DATA      P       130
PRE2SWNG DATA      P       130

11.33.22 >LISTF * LISTING

FILENAME FILETYPE MODE    ITEMS
OUTPRE2  LISTING   P       553
```

Figure V-3

SAMPLE PRINTOUT ILLUSTRATING THE USE OF THE "LISTF" COMMAND

Listing of output files is discussed in Chapter VIII. Note that the listings of the sample region and district plan files in Figures V-1 and V-2 were produced using the "PRINTF" command.

d. Deleting files

Files are erased using the "DELETE" command. Unlike the commands discussed previously, the user enters only the command name after the computer prints the time-of-day. The computer then prompts the user for the additional information it needs to identify the files to be deleted. The "DELETE" command is therefore an example of "interactive" data processing in which the user and the computer converse in the English language rather than in a highly technical programming language. Similar interaction characterizes much of the hypercube system. An example of how the "DELETE" command is used is shown in Figure V-4.

```
11.34.37 >delete
ARE THERE REGION FILES THAT YOU WANT TO ERASE?>y
ENTER NAME OF REGION FILE TO BE ERASED>precnt2
ARE THERE OTHER REGION FILES THAT YOU WANT TO ERASE?>y
ENTER NAME OF REGION FILE TO BE ERASED>pre2swng
ARE THERE OTHER REGION FILES THAT YOU WANT TO ERASE?>n
ARE THERE DISTRICT PLANS THAT YOU WANT TO ERASE?>n
ARE THERE OUTPUT FILES THAT YOU WANT TO ERASE?>y
ENTER NAME OF OUTPUT FILE TO BE ERASED>outpre2
ARE THERE OTHER OUTPUT FILES THAT YOU WANT TO ERASE?>n
DO YOU WANT A LIST OF YOUR FILES PRINTED?>n
```

Figure V-4

SAMPLE PRINTOUT ILLUSTRATING THE USE OF THE "DELETE" COMMAND

VI. Creating and Modifying Region and District Plan Files

This chapter discusses procedures for creating and modifying region and district plan files, and describes various commands which facilitate these procedures.

1. Region Files

Region files are created and/or modified using the "NEWREG," "MODREG," and "CORREG" commands* described below. These commands can be entered whenever the computer prints the time-of-day.

a. "NEWREG" command - the "NEWREG" command is used to create a new region file. Use of the "NEWREG" command involves the inputting of geographic and (optionally) call volume data in the format described in Chapter V. To invoke the command, enter

```
NEWREG
```

after the computer prints the time-of-day. The computer will then ask the user to supply a name to be given to the region file being created. After this information has been entered, the computer will respond

```
EDIT
NEW FILE.
INPUT:
>
```

In reply, key in the number of reporting areas in the region, right justified in columns 1-7 following the ">". On the next line, the user can** key in the numeric identifier of

---

*Users familiar with the "editor" facilities of the time-share system may wish to substitute the "EDIT" command for the commands described in this section.

**Recall that the square mile area and patrolled street miles are optional (see Figure D-3). If these data items are not to be entered in the region file, blanks must be entered instead. The call volume data can also be omitted and added using the "MODREG" command described below.

the first reporting area (right justified in columns 1-7), the x-coordinate (in columns 8-14), the y-coordinate (columns 15-21), the area in square miles (columns 22-28), the call volume (columns 29-35), and the number of patrolled street miles (columns 36-42), and depress the "RETURN" key. Continue keying in the data in the same manner for each of the remaining reporting areas. After all data have been entered depress the "RETURN" key after the computer has printed ">", without entering any characters on the line. The computer will respond

EDIT:
>

In reply, key in

FILE

At this point, the computer should print a listing of the region file that has been created. See Figure VI-1 for an example of the use of the "NEWREG" command.

b. "MODREG" command - the "MODREG" command is used to modify an existing region file by changing or adding call volume data without having to reenter the geographic data. After the user has entered

MODREG

the computer will prompt him for the name of the existing region file that is to be modified, and the name of the new region file being created. After this information has been entered, the computer will respond

ENTER WORKLOAD DATA FOR THE FOLLOWING
REPORTING AREAS:

and will list the identifier of each reporting area in the region file. Following the ">" printed after each reporting area, key in the appropriate call volume, right justified in the first seven columns following the ">". After the data have been entered, the user can specify that the new region file is to be listed. See Figure VI-2 for an example of how the "MODREG" command is used.

c. "CORREG" command - the "CORREG" command is used to correct data that have been erroneously entered or typed in the wrong columns in the line. After the "CORREG" command has been entered, the computer prompts the user for the

```
17.16.25 >newreg
ENTER NAME TO BE GIVEN TO THE REGION FILE BEING CREATED>region1
NEW FILE.
INPUT:
>      16
>      11     2.5      6.0                15
>      21     6.0      3.6                12
>      31     9.5      1.5                 7
>      41     9.8      4.6                 8
>      51     6.5      6.8                10
>      61     4.0      8.2                 8
>      71     8.0      9.0                 8
>      81    10.6      7.1                 6
>      91    12.9      9.5                 3
>     101    10.5     11.2                 5
>     111    12.3     13.4                 3
>     121    14.6     11.6                 2
>     131    14.6     14.1                 1
>     141    17.1     11.8                 2
>     151    17.0     14.3                 5
>     161    18.1     16.8                10
>
EDIT:
>file

       16
       11     2.5      6.0                15
       21     6.0      3.6                12
       31     9.5      1.5                 7
       41     9.8      4.6                 8
       51     6.5      6.8                10
       61     4.0      8.2                 8
       71     8.0      9.0                 8
       81    10.6      7.1                 6
       91    12.9      9.5                 3
      101    10.5     11.2                 5
      111    12.3     13.4                 3
      121    14.6     11.6                 2
      131    14.6     14.1                 1
      141    17.1     11.8                 2
      151    17.0     14.3                 5
      161    18.1     16.8                10
```

Figure VI-1

SAMPLE PRINTOUT ILLUSTRATING THE USE OF THE "NEWREG" COMMAND

```
17.28.-- >modreg
ENTER NAME OF AN EXISTING REGION FILE CONTAINING THE SAME
GEOGRAPHIC DATA AS THE NEW REGION FILE BEING CREATED>region1
ENTER NAME OF REGION FILE TO BE CREATED>region1a
EXECUTION:


 ENTER WORKLOAD DATA FOR THE FOLLOWING REPORTING AREAS:

       11:
>       30

       21:
>       24

        .
        .
        .

      161:
>       20


DO YOU WANT REGION1A LISTED?>yes

      16
      11     2.5     6.6               30
      21     6.0     3.6               24
      31     9.5     1.5               14
      41     9.8     4.6               16
      51     6.5     6.8               20
      61     4.0     8.2               16
      71     8.0     9.0               16
      81    10.6     7.1               12
      91    12.9     9.5                6
     101    10.5    11.2               10
     111    12.3    13.4                6
     121    14.6    11.6                4
     131    14.6    14.1                2
     141    17.1    11.8                4
     151    17.0    14.3               10
     161    18.1    16.8               20
```

Figure VI-2

SAMPLE PRINTOUT ILLUSTRATING THE USE OF THE "MODREG" COMMAND name of the region file being corrected. After the file name has been entered, the computer will respond

```
EDIT:
>
```

Corrections are then made to individual lines in the region file using the following subcommands:

- "LOCATE" - the "LOCATE" subcommand (which can be abbreviated "L") is used to locate the next line in the file which contains a specified sequence of characters. The reporting area identifier in the line to be corrected is a convenient character sequence to use. (Note, however, that the reporting area identifier should be specified as it appears in the region file, even if the identifier is currently incorrect.) The "LOCATE" subcommand is invoked by keying in

    LOCATE $character sequence$

  The computer should respond by printing the first line found with the specified sequence of characters, or EOF if no such line is found.

- "REPLACE" - the "REPLACE" subcommand (abbreviated "R") is used to replace the previously located line. It is invoked by keying in

    REPLACE newline

  where "newline" is the replacement line, properly spaced and separated from the command by a single space. To list the new line, enter

    PRINT

- "INSERT" - the "INSERT" subcommand (abbreviated "I") is used to insert a new line of data immediately following the previously located line. To use the "INSERT" subcommand, enter

    INSERT newline

  where "newline" is the insertion line properly spaced and separated from the command by a single space.

- "DELETE" - the "DELETE" subcommand (abbreviated "DE") is used to delete the previously located line. To use the "DELETE" subcommand enter

    DELETE

- o "TOP" - the "TOP" subcommand is used to move to the top of the file. The "TOP" command, invoked simply by entering

  TOP

  must be used prior to attempting to locate a line in the file which precedes the last line located, since the "LOCATE" subcommand searches only those lines between the last line located and end of the file.

After all corrections have been made, key in

FILE

to terminate the "CORREG" command. An example of the "CORREG" command is shown in Figure VI-3.

The procedure for creating, modifying, and correcting region files is schematically summarized in Figure E-2.

2. <u>District Plan Files</u>

Unlike region files, district plan files are somewhat irregular in that several different formats must be used to represent individual data items within the file. While the exact columns in which the data are placed are unimportant the order in which the data are entered is crucial, as is the placement of delimiters such as quotes, blanks, and semicolons. In addition, certain combinations of input data items are not allowed; and for some items, only certain values or ranges of values are permitted.

In order to facilitate the creation of district plan files, the developers of the hypercube software have produced a companion program, referred to as the "monitor," which allows the user to create or modify district plan files in a conversational way. The monitor -- not the user -- formats the file. In addition, warnings are printed to alert the user when he specifies an invalid data value or combination of values. The monitor is also capable of providing novice users with tutorial explanations of features available and user input that is being requested, either by printing the explanation at the user's terminal, or by referring him to an appropriate explanation in the hypercube user's manual.* The disadvantage of using the monitor to create or modify district plan files is that for users who thoroughly understand the format of district plan files, it is relatively expensive. For this reason, users have the option of creating

*The user's manual referenced is "Hypercube Queuing Model: User's Manual," R-1688/2-HUD, July 1975.

```
17.32.09 >CORREG
ENTER NAME OF REGION FILE TO BE CHANGED>REGION1A
EDIT:
>LOCATE $131$
    131    14.6    14.1               2
>REPLACE      131    14.6    14.1                  1
>PRINT
    131    14.6    14.1               1
>TOP
>L $121$
    121    14.6    11.6               4
>REPLACE      121    14.6    12.1                  4
>PRINT
    121    14.6    12.1               4
>L $51$
    151    17.0    14.3              10
>TOP
>L $51$
     51     6.5     6.8              20
>R      51     6.5     6.7               23
>PRINT
     51     6.5     6.7              23
>FILE
DO YOU WANT REGION1A LISTED?>Y

     16
     11     2.5     6.0              30
     21     6.0     3.6              24
     31     9.5     1.5              14
     41     9.8     4.6              16
     51     6.5     6.7              23
     61     4.0     8.2              16
     71     8.0     9.0              16
     81    10.6     7.1              12
     91    12.9     9.5               6
    101    10.5    11.2              10
    111    12.3    13.4               6
    121    14.6    12.1               4
    131    14.6    14.1               1
    141    17.1    11.8               4
    151    17.0    14.3              10
    161    18.1    16.8              20
```

<u>Figure VI-3</u>

SAMPLE PRINTOUT ILLUSTRATING THE USE OF THE "CORREG" COMMAND

and modifying district plan files with or without the assistance of the monitor.

a. Creating and modifying district plan files using the monitor

In order to use the monitor program to create or modify a a district plan file, the amount of available core storage (i.e., the area in which programs are loaded, variables and intermediate results are stored, and calculations are performed) must be increased. This is done by entering the command

```
SET CORE 384
```

after the computer prints the time-of-day. The computer should respond

```
CSS.301  11/03/76
time-of-day>
```

At this point, one of the following commands can be entered to invoke the monitor program:

- "MONITNEW" command - the "MONITNEW" command is used to create a new district plan file. Use of this command will require the user to specify all required data items (see Figure D-3) including patrol and dispatch policies and a district configuration (i.e., an assignment of each reporting area in the region to one or more districts). This is in contrast to the "MONITOLD" command described below which enables the user to retain features contained in an existing district plan file without having to reenter all of the information. After the "MONITNEW" command has been entered, the user is asked to supply the name of an existing region file containing geographic and call volume data for the jurisdiction of interest, and a name to be given to the district plan file being created. When this information has been entered, the computer should respond

  ```
  EXECUTION:
  NSF/RANN INTERACTIVE HYPERCUBE SYSTEM
  MONITOR HERE.  WHEN IN DOUBT, TYPE '?'.
  explanatory information
  ENTER COMMAND:

  >
  ```

  At this point, any of the monitor subcommands discussed below can be entered.

o "MONITOLD" command - the "MONITOLD" command is used to create a new district plan file by modifying the contents of an existing district plan file. After the command has been entered, the user is asked to supply the name of the existing district plan file being modified, as well as the names of the appropriate region file and the new district plan file to be created. After this information has been entered, the computer responds as described above for the "MONITNEW" command. Any monitor subcommand can then be entered.

Once the point at which the computer prints

```
ENTER COMMAND:

>
```

is reached, the user begins communicating with the monitor, rather than with the NCSS system. Until the user terminates execution of the monitor program by entering the "KL" command (described in Chapter IV) or the appropriate monitor subcommand, NCSS/hypercube commands are not recognized by the computer. Rather, the user must enter one of the following when the computer prompts him for a response (by printing ">"):

- o a monitor subcommand if the computer's last request was "ENTER COMMAND:";
- o the data item(s) requested by the computer;
- o "?" to obtain a more detailed explanation of the information that the computer has requested; or
- o "Q" to terminate the last command entered. (In some cases, "Q" is not a valid response, and the computer will so inform the user.)

The monitor subcommands are briefly discussed below.* These subcommands have been grouped according to the functions they perform.

(1) Subcommands used to describe patrol and response activities

---

*Emphasis is placed on describing the uses of each subcommand, and on providing information not readily available as part of the monitor's tutorial capabilities. The use of many of the subcommands is illustrated in the sample terminal session in Appendix B.

o "CONFIG" subcommand - the "CONFIG" subcommand is used to specify or modify the district configuration. Districts are created by assigning a numeric identifier (32767 or less) to the district, and listing the reporting areas in the district. Since terminal input is limited to 80 characters, all reporting areas must be listed on a single line if possible. If this is not possible, only as many reporting areas as can be specified in 80 characters should be listed initially, with the remainder added later (also using the "CONFIG" command). To create an overlay district (i.e., a district that completely overlaps one or more previously created districts), assign a unique numeric identifier to the new district and when the computer prompts the user with

REPORTING AREAS:

enter

OVERLAY list

(which can be abbreviated "OV") where "list" is a list of the existing districts that are to be overlaid. The district configuration can also be modified using the "CONFIG" subcommand by adding, deleting, or combining districts, adding or deleting reporting areas from a district, and transferring reporting areas from one district to another. Preventive patrol factors can also be modified.

o "SPEED" subcommand - the "SPEED" subcommand is used to specify or modify the speed of patrol units when responding to calls for service. Separate speeds can be specified for travel in the direction of the X- and Y- coordinate axes used to measure the geographic centers of reporting areas. If the user enters

SPEED X

or

SPEED Y

the computer prompts him for an x-directional or y-directional response speed, respectively. If the user enters

SPEED XY

he is prompted for a response speed to apply to travel in both the x and y direction. If the user enters

SPEED

he is prompted for both an x- and y-directional response speed if an individual x-speed has previously been specified, or for a single response speed otherwise.

- "PATROL" subcommand - the "PATROL" subcommand is used to specify or modify the speed of response units when on preventive patrol. The patrol speed is used to calculate the frequency of preventive patrol passings. A patrol speed should be specified only if data on patrolled street miles have been included in the region file. To specify a patrol speed, enter

  PATROL patrol-speed

  where "patrol-speed" is the effective patrol speed in miles per hour. To remove the specification of a patrol speed in the district plan file, enter

  PATROL 0

(2) Subcommands used to specify unit workloads

- "WORKLOAD" subcommand - the "WORKLOAD" subcommand is used to specify or modify the average number of calls for service per hour and the average service time, in minutes, per call. After the subcommand has been entered, the computer prompts the user for the number of workload levels for which the hypercube program is to compute performance measures, the average service time, the (lowest) number of calls per hour for which performance measures are to be computed, and, if more than one workload level is specified, an incremental call arrival rate used to compute the second and subsequent workload levels.

- "VST" subcommand - the "VST" subcommand is used to specify or modify average service times for the individual response units. In addition, it is used to list existing variable service times. After the subcommand has been entered, the computer prompts the user for an option number: option 1 is used to list the service times, and option 2 is used to enter or modify the variable service times. When option 2 is specified, the the user is further prompted for the service times (one for each unit). Depressing the "RETURN" key at this point without entering any service times eliminates all variable service times. Note that when variable service times are specified or modified, the average service time is recalculated as the average of the variable service times. Similarly, when variable service times have been specified and the "WORKLOAD" command is used to modify the average service time, the variable service times are scaled such that their average is the same as the specified average service time.

- <u>"ADJUST" subcommand</u> - the "ADJUST" subcommand is used to adjust the call rate to account for multiple unit dispatches and/or non-call-for-service workload which causes units to be unavailable for dispatch to a call for service. If the user wants to adjust for multiple unit dispatches, he is prompted for the fraction of calls requiring two or more units and the average service time for the first, second, etc. dispatched unit. If the user wants to adjust the call rate to account for non-call-for-service workload, he is prompted for the average number of minutes a response unit spends on non-call-for-service work per hour. Note that the adjustments made depend on the number of units, the call rate, and the average service time. Therefore, these variables should not be changed after the "ADJUST" command has been used.

If calls arriving when all units are busy are queued, care must be taken in specifying workload data. In particular, if the highest call arrival rate and average service time specified as a result of using the "WORKLOAD," "VST," and "ADJUST" commands are such that*

(highest call rate)x(average service time)>(number of units)

the queue is said to be "saturated." In such cases, the hypercube program is unable to compute performance measures. Consequently, when the monitor prints a warning indicating that the queue will be saturated, the user should increase the number of units by defining additional districts, decrease the highest call arrival rate or average service time, or specify that calls are not to be queued.

---

*The symbol ">" is read "is greater than."

(3) Subcommands used to specify the dispatch policy

- "POLICY" subcommand - the "POLICY" subcommand is used to specify which of five dispatch policies available in the hypercube model most accurately describes the selection process used by dispatchers in assigning a response unit to a call for service. The dispatcher's selection process usually depends heavily on which unit he "perceives" to be closest to the call for service. This perception depends on how accurately he knows the location of calls and cars and how he estimates travel times. Consequently, the five available dispatch policies differ according to the dispatcher's knowledge of car and call locations:

  -- SCM (Strict Center of Mass) - the SCM policy assumes that the dispatcher has minimal knowledge of both car and call locations. Regarding the call, the dispatcher assumes that it is located exactly in the center of the district from which it has originated, where "center" is defined in terms of the geographic distribution of arriving calls. Regarding the car, the dispatcher assumes that it too is centrally located in its district, where "center" in this case is defined by the car's preventive patrol habits. Travel distance is measured from car center to call center.

  -- ESCM (Expected Strict Center of Mass) - the ESCM policy assumes that the dispatcher is slightly more familiar than under SCM with the geographic distribution of incoming calls in each district, and with the district cars' patrol patterns when on preventive patrol. While the dispatcher knows neither the call or car locations exactly, he is able to use his knowledge of their usual locations to estimate more accurately the average travel distance (or travel time) for each car when responding to calls in each of the districts. He does this by intuitively averaging travel distances from each reporting area in which the car may be located, when it gets the assignment, to each reporting area from which the call might originate.

CONTINUED

1 OF 3

-- MCM (Modified Center of Mass) - the MCM policy assumes that the dispatcher always imagines an available response unit to be located exactly at the center of its district, where center is defined by the car's preventive patrol habits. Regarding the call location, however, the dispatcher knows its reporting area (he assumes that the scene of the incident is at the center of the reporting area). Because most dispatchers become familiar with street addresses in their dispatching areas, but have little location information about cars on patrol, MCM is probably the best model of a manual dispatch operation manned by reasonably experienced dispatchers.

-- EMCM (Expected Modified Center of Mass) - The EMCM policy assumes even more knowledgeable and capable dispatchers than are assumed under MCM. Like MCM, a dispatcher knows the reporting area from which each call originates. Regarding the car's location, however, the dispatcher uses his knowledge of its preventive patrol patterns to average the travel distance (or time) from each reporting area in which the car might be patrolling to the call's reporting area. This gives the most accurate travel distance (or time) estimate of the four policies thus far described for selecting the car best able to respond to the call at hand. Consequently, EMCM represents the most sophisticated type of manual dispatching operation when the true positions of the patrol units are unknown.

-- AVL (Automatic Vehicle Location) - The AVL policy assumes that the dispatcher knows not only the reporting area from which each call originates, but also the reporting area in which each car is located. The exact travel distance can then be calculated from the center of the car's reporting area to the center of the call's reporting area.

Figure VI-4 summarizes the dispatch policies in terms of the dispatcher's knowledge of call and car locations.

o "COMPARE" subcommand - the "COMPARE" subcommand is also used to specify AVL dispatching. When AVL dispatching is specified using the "COMPARE" subcommand, dispatch error probabilities (i.e., the fraction of calls to which other than the closest available unit would be dispatched) are also computed assuming the dispatch policy specified using the "POLICY" subcommand. To cancel the effect of the "COMPARE" subcommand, "COMPARE" is entered a second time.

- "QUEUE" subcommand - the "QUEUE" subcommand is used to specify the procedure used for handling calls for service which arrive when all units are unavailable. Users may specify one of two alternatives: calls may be queued until a response unit becomes available, or calls may be assigned to a backup unit (e.g., detectives, traffic car, etc.) not explicitly represented in the district plan other than by noting their presence. (Procedures in which some calls are queued and others are assigned to backup units are not representable.) If calls are queued, they are dispatched to response units on a first-arrived, first-served basis with no consideration given to call priority. If calls are assigned to backup units, it is assumed that enough backup units are available to avoid all queuing of calls for service, and that backup units never turn over an assigned call to a response unit. Use of backup units have the effect of decreasing the workload of district cars. Data on the workload of backup units, other than the fraction of calls they handle, are not available.

- "FRST" subcommand - the "FRST" subcommand is used to specify whether the district car is to be dispatched to calls for service in its district whenever it is available, regardless of whether the dispatcher perceives another unit to be closer to the call. Specification that the district car is to be given first preference for dispatch to calls in its district is ignored when the AVL dispatch policy is used. If district car first is specified, and districts overlap, it is the lowest numbered unit (i.e., the one specified first in the district plan file) whose district contains the call that is given first dispatch preference.

		CAR'S LOCATION		
DISPATCH POLICY		Assumed exactly at car center*	Pattern of patrol among reporting areas known	Reporting area known exactly
CALL'S LOCATION	Assumed at call center** or distributed over reporting areas	SCM	ESCM	-
	Reporting area known	MCM	EMCM	AVL

*Car center defined by time car spends on preventive patrol in each reporting area in the district.

**Call center defined by distribution of arriving calls over the reporting areas in the district.

Figure VI-4

PROPERTIES OF ALTERNATIVE DISPATCH POLICIES

- "FRONT" subcommand - the "FRONT" subcommand is similar to the "FRST" subcommand in that it is used to specify that a particular unit is to be assigned first dispatch preference in certain reporting areas. Unlike the "FRST" subcommand, the user is prompted for the unit identifier and a list of reporting areas which must be entered in 80 characters or less. If all reporting areas to which the unit is to be dispatched first cannot be entered in 80 characters, then the "FRONT" subcommand must be reused to enter additional reporting areas. Assignments of first dispatch preferences to a unit are removed by using the "FRONT" subcommand and depressing the "RETURN" key when prompted for the list of reporting areas. Note that if district car first is specified, and the "FRONT" subcommand is used to assign first dispatch preference to a non-district car in some reporting areas, then two or more cars will be equally preferred by the dispatcher in these reporting areas. In this case, calls in these reporting areas are split evenly among these units when more than one are available. The "FRONT" subcommand should not be used if AVL dispatching is to be used.

- "BACK" subcommand - the "BACK" subcommand is used to assign last dispatch preference to a particular unit in certain reporting areas (i.e., to specify that the unit is to be dispatched to calls in those reporting areas only if it is the only unit available). After entering the subcommand, the user is prompted for the unit identifier and a list of reporting areas which must be entered in 80 characters or less. Assignments of last dispatch preference to a unit are removed by using the "BACK" subcommand and depressing the "RETURN" key when prompted for the list of reporting areas. The "BACK" subcommand should not be used if AVL dispatching is to be used.

- "MIDDLE" subcommand - the hypercube program computes a "cost" associated with dispatching each unit to calls for service in each reporting area. These costs are related to expected travel times from car to call locations, and depend on the user specified dispatch policy and preventive patrol factors. The "MIDDLE" subcommand is used to replace selected computed costs with user specified costs which must be between 0 and 999. (Dispatch costs are set to 0 when first dispatch preferences are specified using the "FRST" or "FRONT" subcommands, and to 999 when last dispatch preferences are specified using the "BACK" subcommand.) After entering the command, the user is prompted for the unit identifier, a dispatch cost, and a list of reporting areas (80 characters or less) to which the specified cost of dispatching that unit is to apply. To cancel all previous specifications of dispatch costs for a unit, depress the "RETURN" key when prompted for the list of reporting areas. The "MIDDLE" subcommand can be used to specify arbitrary fixed preference dispatch policies. It should not be used if AVL dispatching is to be used.

The monitor places no restrictions on the reporting areas specified when using the "FRONT," "BACK," and "MIDDLE" subcommands. As a result, conflicting specifications can result (e.g., a unit might be assigned both first and last dispatch preference in a reporting area). When this occurs specifications from the "MIDDLE" subcommand take precedence over those from the "BACK," "FRONT," and "FRST" subcommands, while specifications from the "BACK" subcommand take precedence over those from the "FRONT" and "FRST" subcommands.

(4) <u>Subcommands used to modify hypercube input, output, and assumptions</u>

o <u>"D_SCALE" subcommand</u> - in order to use the x, y coordinates of reporting area centers, the hypercube program must convert the coordinates in the region file to miles. The "D_SCALE" subcommand is used to specify the scaling factor by which the coordinates must be multiplied to convert them to miles. To specify this factor, enter the subcommand followed by the scaling factor. For example, if the coordinates in the region file are measured in units of one-tenth mile, enter

D_SCALE 0.10

If the coordinates in the region file are already measured in miles, the "D_SCALE" subcommand need not be used.

o <u>"TXOV" subcommand</u> - as discussed in Chapter III, the x,y coordinates of reporting area centers are used in computing inter-reporting area travel times using the manhattan distance metric. If, because of barriers to travel, the use of the manhattan metric produces unrealistic estimates of the travel time between selected pairs of reporting areas, the "TXOV" subcommand can be used to specify actual travel times directly. After entering the subcommand, the user is prompted to

ENTER TRIPLETS:

To specify the travel time from reporting area 14 to reporting area 211, for example, enter

14 211 travel-time

where "travel-time" is the user's estimate of the travel time in minutes. Note that the hypercube program does not assume that the travel time from area 211 to area 14 is the same as the travel time from area 14 to area 211. To specify travel times for both directions, enter

14 211 travel-time 211 14 travel-time

To modify a previously entered travel time estimate, reuse the "TXOV" subcommand specifying the appropriate pair of reporting areas and the new travel time. To remove all travel times previously specified using the "TXOV" subcommand, enter

TXOV DELETE

or

TXOV D

- <u>"CORTM" subcommand</u> - the "CORTM" subcommand is used to specify the constant of proportionality used by the hypercube program to compute intra-reporting area travel times (see Chapter III). To specify a constant, enter

  CORTM constant

  If the user does not specify a constant using the "CORTM" subcommand, zero is assumed (i.e., all intra-reporting area travel times will be zero). If the region file does not contain data on the size of reporting areas, the "CORTM" subcommand should not be used. A commonly specified value of CORTM is 0.667; for increased values of intra-reporting area travel times use a larger value for CORTM (and, correspondingly, a lower value for decreased times.)

- "TITLE" subcommand - the "TITLE" subcommand is used to specify up to 50 characters of information to be printed as heading information in the hypercube output. Suggested information items to include in the title are the region and watch being analyzed, the date, distinguishing features of the district plan, etc. Note that the title specified is completely independent of the names given to the region and district plan files.

- "GLOSSARY" subcommand - the "GLOSSARY" subcommand can be used to specify terminology to be used in the hypercube output to refer to districts, reporting areas, response units, travel times, and calls for service. For example, a user may specify that the output is to refer to "beats" rather than "districts." After entering the subcommand, the user is prompted for the number of the option he wants to use. Options are available for listing the glossary, terminating the "GLOSSARY" subcommand, and entering or changing 'R_DIST,' 'ATOM,' 'R_UNIT,' 'T_COST,' 'CFS,' 'NM_DIST,' and 'NM_UNIT' which are used in the subcommand as generic names for referring to the various terms that can be modified. These options are summarized in Figure VI-5. Note that both 'R_UNIT' and 'NM_UNIT' refer to "response units," and both 'R_DIST' and 'NM_DIST' refer to "district." The difference is that terms specified for 'NM_UNIT' and 'NM_DIST' are used to refer to particular units and districts in the hypercube output and are limited to eight characters or less, whereas 'R_UNIT' and 'R_DIST' are used to refer to units and districts in general and are limited to 18 and 8 characters or less, respectively. Figure VI-6 illustrates how the terms specified in the glossary affect the hypercube output.

(5) Subcommands used to specify which of the available hypercube output tables are to be generated

The hypercube program is capable of generating voluminous amounts of output. Some of the tables produced may not be

Option	Generic Name Modified	Maximum Length (No. of Characters)	Default Definition
2	'R_DIST'	8	DISTRICT
3	'ATOM'	8	ATOM
4	'R_UNIT'	18	RESPONSE UNIT
5	'T_COST'	18	TRAVEL TIME
6	'CFS'	18	CALLS FOR SERVICE
7	'NM_UNIT'	8	UNIT
8	'NM_DIST'	8	DIST

1	Option used to list the current glossary
9	Option used to terminate the "GLOSSARY" subcommand

Figure VI-5

OPTIONS OF THE "GLOSSARY" SUBCOMMAND

```
PROBLEM TITLE: SAMPLE 3-CAP RUN WITH 7 REPORTING AREAS
    * ITERATIVE APPROXIMATION METHOD USED *
    NUMBER OF ITERATIONS REQUIRED:          3
UNLIMITED CAPACITY QUEUE WITH 1+ST-COME 1+ST-SERVED QUEUE DISCIPLINE
RUN NUMBER:  1
******R+UNIT******  ...TOTAL NUMBER OF =  3
**ATOM**  ...TOTAL NUMBER OF =   7
AVERAGE SERVICE TIME=  25.00 MINUTES
AVERAGE NUMBER PER HOUR OF ********CFS******** =   2.880
AVERAGE NUMBER PER  25.00 MINUTES OF ********CFS******** =   1.200
AVERAGEUTILIZATION FACTOR
   (IN THE CASE OF UNLIMITED LINE CAPACITY)=  0.400
REGION-WIDE AVERAGE ******T+COST******=   2.197 MINUTES
AVERAGE ******T+COST****** FOR QUEUED CALLS=   2.906 MINUTES
PROBABILITY OF SATURATION= 0.14118
REGION-WIDE AVERAGE WORKLOAD (% TIME BUSY)= 0.40000
STANDARD DEVIATION OF WORKLOAD=   0.010
MAXIMUM WORKLOAD IMBALANCE= 0.02019
FRACTION OF DISPATCHES THAT ARE INTER-*R+DIST* = 0.35255
PERFORMANCE MEASURES THAT ARE SPECIFIC TO EACH ******R+UNIT******
```

NAME	ID OF ******R+UNIT****** NO	WORKLOAD OF UNIT	% OF MEAN	FRACTION OF DISPATCHES OUT OF *R+DIST*	% OF MEAN	AVERAGE ******T+COST******
NM+UNT	1	0.388	97.1	.2351	66.7	2.753
NM+UNT	2	0.409	102.1	.2975	84.4	2.365
NM+UNT	3	0.403	100.8	.5209	147.8	1.493

```
PERFORMANCE MEASURES THAT ARE SPECIFIC TO EACH *R+DIST*
```

NAME	ID OF *R+DIST* NO	WORKLOAD OF *R+DIST*	% OF MEAN	FRACTION OF DISPATCHES INTER-*R+DIST*	% OF MEAN	AVERAGE ******T+COST******
NM+DST	1	0.450	112.5	.3418	97.0	2.905
NM+DST	2	0.450	112.5	.3609	102.4	2.330
NM+DST	3	0.300	75.0	.3556	100.9	0.935

* Glossary items are underlined in this table. Asterisks in these items have been used to represent the length and position of the terms in the output.

Figure VI-6

SAMPLE HYPERCUBE OUTPUT SHOWING THE USE OF GLOSSARY TERMS* of interest to many users. Other tables will not change from one run to the next unless certain features of the district plan are changed. For this reason, several subcommands are available for specifying whether the various tables are to be produced. These subcommands are summarized in Table VI-1.

Conceptually, the production of each table can be viewed as being controlled by a switch: when the switch is "on," the table is produced, and when the switch is "off," the table is not produced. The subcommands shown in Table VI-1 have the effect of "flipping" the appropriate switch. For example, if the district plan specifies that the table of dispatch costs is not to be printed when the "PRNT_COST" subcommand is used, the plan is changed to specify that the table is to be printed.

In addition, the following subcommands can be used to modify several switches simultaneously:

- "PRNT_ALL" subcommand - the "PRNT_ALL" subcommand is used to turn all switches "on" except the one controlling the printing of the table of inter-reporting area travel times.

- "NO_PRNT" subcommand - the "NO-PRNT" subcommand is used to turn all switches "off" except the one controlling the printing of the table of inter-reporting area travel times.

Note that until the user specifies otherwise, all switches are off. In this case, only tables showing region, unit, and district performance measures are generated. (These tables are always produced and cannot be suppressed.)

(6) Subcommands used to list information contained in the district plan file

- "PRINTDIST" subcommand - the "PRINTDIST" subcommand is used to list the district configuration specified in the plan (i.e., a list is printed showing which reporting areas are contained in each district). Preventive patrol factors can also be listed.

- "INSPECT" subcommand - the "INSPECT" subcommand is used to list reporting areas in the region file that have not been assigned to any district, and to list reporting areas contained in more than one district.

Table VI-1

SUBCOMMANDS USED TO CONTROL THE PRINTING OF HYPERCUBE OUTPUT

Subcommand *	Tables Affected	Sample Table
"PRNT_ATOM"	Tables showing performance measures specific to each reporting area	Figures VIII-10, VIII-11, and VIII-16
"PRNT_CFS"	Table showing the distribution of calls for service by reporting area	Figure VIII-3
"PRNT_COST"	Table showing the estimated cost of dispatching each response unit to each reporting area	Figure VIII-7
"PRNT_PATROL"	Table showing the number of patrolled street miles in each reporting area	Figure VIII-4
"PRNT_SP_ALC"	Table showing fraction of available time each response unit spends in each reporting area	Figure VIII-8
"PRNT_TR"	Table showing inter-reporting area travel times	Figure VIII-5
"PRNT_TT"	Table showing mean travel times of each response unit to each reporting area.	Figure VIII-6
"PRNT_VST"	Table showing each response unit's service time	Figure VIII-12

*Note that the "underscore" symbol used in these names, such as in PRNT_ATOM, is a required character and may not be replaced with a blank space.

- "SUMMARY" subcommand - the "SUMMARY" subcommand is used to list all other features of the district plan. Figure VI-7 shows a sample "summary" listing. The format used to represent the basic data items in the district plan (e.g., number of units, number of reporting areas, title, etc.) is self-explanatory. Most other features of the district plan are usually summarized by listing the subcommand used to specify them (e.g., 'PRNT_CFS', 'PATROL' 7.5, 'COMPARE'). Features specified as a result of the "FRONT," "BACK," "MIDDLE," "VST," and "TXOV" subcommands are displayed using the format for the analagous data cards described in "Hypercube Queuing Model: User's Manual."

- "TYPOUT" subcommand - the "TYPOUT" subcommand is used to print the contents of the district plan file exactly as it will be stored. The subcommand is equivalent to the "PRINTF" command described in Chapter V, except that it is used within the monitor.

(7) Miscellaneous subcommands

- "STATISTICS" subcommand - certain calculations within the hypercube program can be made "exactly" or they can be made using certain mathematical approximations which greatly simplify the procedure and produce results which are generally within two percent and almost always within five percent of those produced by the exact model. The "STATISTICS" subcommand is used to specify which model is to be used. The following should be considered in selecting the model:

  - The exact model is much more expensive, and requires much more core storage (see Chapter VII) than the approximate model;

  - The exact model cannot be used if more than 15 districts are specified; and

  - The approximate model cannot be used if AVL dispatching or variable service times are specified.

```
        SUMMARY OF DISTRICT PLAN

NUMBER OF UNITS:         3
NUMBER OF REPORTING AREAS:          7
TITLE OF PLAN: SAMPLE 3-CAR RUN WITH 7 REPORTING AREAS
PATROL UNIT RESPONSE SPEED:  10.00
SCALING FACTOR:   0.019
NUMBER OF WORKLOAD LEVELS:          1
PATROL UNIT SERVICE TIME:    25.0
NUMBER OF CALLS FOR SERVICE PER HOUR:     2.9
DISPATCH POLICY:  SCM
NO SPECIAL PREFERENCE FOR DISTRICT CAR.
INFINITE CAPACITY QUEUE.
STATISTICS GENERATED:  ONLY APPROXIMATE STATISTICS

'PRNT←SP←ALC'
'PRNT←CFS'
'PRNT←VST'
'PRNT←PATROL'
'PRNT←TT'
'PRNT←COST'
'PRNT←TR'
ATOM DATA WILL BE PRINTED
```

Figure VI-7

SAMPLE LISTING PRODUCED BY THE "SUMMARY" SUBCOMMAND

- "CREATE" subcommand - use of the "CREATE" subcommand is a convenient way of specifying the basic data required in a new district plan file. The "CREATE" subcommand is equivalent to successive uses of the "TITLE," "SPEED," "POLICY," "FRST," "QUEUE," "STATISTICS," "CONFIG," "WORKLOAD," "SUMMARY," and "INSPECT" subcommands. Note that the "CREATE" subcommand also resets all default features of the district plan (see Figure D-3).

- "MODIFY" subcommand - use of the "MODIFY" subcommand is a convenient way of making many changes in the basic data in an existing district plan file. It is equivalent to successive uses of the commands listed in the description of the "CREATE" subcommand. Defaults are not reset when the "MODIFY" subcommand is used.

- "STORE" subcommand - the "STORE" subcommand is used to store a created or modified district plan file on disk without terminating the monitor program. This provides a safeguard against the loss of previously input data or modifications in the event of an interrupted terminal session. Should such an interruption occur, the stored district plan will reflect all input up to the last time the "STORE" subcommand was used or the last time the district configuration was changed (at which time the district plan file is automatically stored).

- "LISTCMDS" subcommand - the "LISTCMDS" subcommand is used to list a brief description of the commands available for entering or modifying basic features of a district plan.

- "LISTADVCMDS" subcommand - the "LISTADVCMDS" subcommand is used to list a brief description of the subcommands available for specifying more advanced features of the district plan.

(8) Subcommands used to terminate the monitor program

- "SAVE" subcommand - the "SAVE" subcommand is used to terminate the monitor program after first storing the district plan on disk. The district plan file thus created will contain all modifications made during the terminal session.

- "EXIT" subcommand - the "EXIT" subcommand is used to terminate the monitor program without storing the district plan. Note, however, that a district plan file (possibly incomplete) will have been created if the "STORE" subcommand was used or the district configuration was modified during the terminal session.

b. Creating and modifying district plan files without using the monitor

Users wishing to create or modify district plan files without using the monitor program can do so using the commands described in this section. Since the user must ensure that the resulting district plan file is properly formatted, and that no constraints are violated (i.e., no error checking facilities such as those provided by the monitor are available), the procedures described in this section should be attempted only by users thoroughly familiar with the format of district plan files, and with hypercube restrictions on the features they can contain. The latter are summarized in Figure D-3. The former can be gained by referring to "Hypercube Queuing Model: User's Manual." The format of district plan files is the same as the format of the data decks described in the user's manual with the following exceptions:

- 'ATOM_NO' instruction - if reporting area identifiers are non-sequential, the "ATOM_NO" instruction is entered into the district plan file but the reporting areas are not since they are in the region file.

- 'BACK' instruction - if the 'BACK' instruction is used, the actual reporting area identifiers in the region file should be entered.

- 'CORTM' instruction - if the 'CORTM' instruction is to be used, enter the constant of proportionality, but not the sizes of the reporting areas since these data are in the region file.

- 'FRONT' instruction - the actual reporting area identifiers in the region file should be used in the 'FRONT' instruction.

- 'GLOSSARY' instruction - the names given to individual units (i.e., to 'NM_UNIT(I)') should be the same for all units if the district plan file is to be modified using the monitor. Similarly the names given to individual districts 'NM_DIST(I)' should be the same.

- 'LAM' instruction - reporting area workloads should not be entered following the 'LAM' instruction since these data are in the region file.

- 'MIDDLE' instruction - the actual reporting area identifiers in the region file should be used in the 'MIDDLE' instruction.

- 'PATROL' instruction - the patrolled street miles should not be included in the 'PATROL' instruction since these data are in the region file.

- 'RERUN' instruction - the 'RERUN' instruction should not be used in any district plan file that will be modified using the monitor.

- 'S' instruction - the actual reporting area identifiers in the region file should be used in the 'S' instruction.

- 'SS' instruction - the actual reporting area identifiers in the region file should be used in the 'SS' instruction.

- 'TX' instruction - x,y coordinates of reporting area centers should not be entered following the 'TX' instruction since these data are in the region file.

The following instructions can also be entered:

- 'ALLOCATE' instruction - the 'ALLOCATE' instruction should be used if more than one workload level is specified.

- 'AVL' instruction - the 'AVL' instruction is used to specify the AVL dispatching policy.

- 'COMPARE' instruction - the 'COMPARE' instruction is used to specify that dispatch error probabilities are to be computed.

o 'D_SCALE' instruction - the 'D_SCALE' instruction should be entered followed by a scaling factor to specify a constant multiplier required to convert x,y coordinates in the region file to miles.

o 'PRNT_CFS', 'PRNT_COST', 'PRNT_PATROL', 'PRNT_SP_ALC', 'PRNT_TT', and 'PRNT_VST' instructions - these instructions are used to request the printing of individual hypercube tables.

The ordering of all instructions is summarized in Table VI-2.

(1) <u>"NEWPLAN" command</u> - the "NEWPLAN" command is used to create a new district plan file. To invoke the command, enter

NEWPLAN

after the computer prints the time-of-day. The computer will then request a name to be given to the district plan file being created. After this information has been entered, the computer will respond

EDIT
NEW FILE.
INPUT:
>

In reply key in the instructions to be included in the district plan file in the order and format described above and in "Hypercube Queuing Model: User's Manual." After all instructions have been entered, depress the "RETURN" key after the computer has printed ">", without entering any characters on the line. The computer will respond

EDIT:

>

In reply, key in

FILE

At this point, the computer should print a listing of the district plan file that has been created. See

Table VI-2

ORDERING OF INSTRUCTIONS IN DISTRICT PLAN FILES

1. Basic program specifications
2. 'GLOSSARY'
3. 'TITLE'
4. 'PRNT_CFS,' 'PRNT_COST,' 'PRNT_PATROL,' 'PRNT_SP_ALC,' 'PRNT_TR,' 'PRNT_TT,' and/or 'PRNT_VST'
5. 'NO_PRNT_AT'
6. 'ATOM_NO'
7. 'LAM'
8. 'S' and/or 'SS'
9. 'D_SCALE'
10. 'SPEED' or 'XSPEED' and 'YSPEED'
11. 'PATROL'
12. 'TX,' 'CORTM,' and 'TX_OV,' or 'TR'
13. 'SCM,' 'ESCM,' 'MCM,' 'EMCM,' or 'AVL'
14. 'ALLOCATE'
15. 'COMPARE'
16. 'FRST'
17. 'DISP_OV_RD'
18. 'CAP'
19. 'SERVTM' or 'VAR_SER_TM'
20. 'RUN'
21. 'FRONT,' 'BACK,' and/or'MIDDLE'
22. 'END_OV_RD'

Figure VI-8 for an example of the use of the "NEWPLAN" command.

(2) "MODPLAN" command - the "MODPLAN" command is used to modify an existing district plan file. After the "MODPLAN" command has been entered, the computer prompts the user for the name of the district plan file being modified. After the file name has been entered, the computer will respond

EDIT:

>

Modifications are then made to individual lines in the district plan file using the same subcommands discussed in the description of the "CORREG" command. After all modifications have been made, key in

FILE

to terminate the "MODPLAN" command. An example of the "MODPLAN" command is shown in Figure VI-9.

The procedures for creating and modifying district plan files are summarized in Figure E-3.

```
12.01.38 >newplan
ENTER NAME TO BE GIVEN TO THE DISTRICT PLAN FILE BEING CREATED>sampland1
NEW FILE.
INPUT:
>m=3 r=7 num=1 eststat=1;
>'title' 'sample 3-car run with 7 reporting areas'
>'prnt←cfs'
>'atom←no'
>'lam'
>'ss' 1 3 1 1.00 2 0.00 3 1.00
>'ss' 2 3 4 1.00 6 1.00 7 2.00
>'ss' 3 1 5 1.00
>'d←scale' 0.019
>'speed' 10.0
>'tx'
>'scm'
>'cap'
>'servtm' 25.0
>'run' 2.88 0.00
>
EDIT:
>file

M=3 R=7 NUM=1 ESTSTAT=1;
'TITLE' 'SAMPLE 3-CAR RUN WITH 7 REPORTING AREAS'
'PRNT←CFS'
'ATOM←NO'
'LAM'
'SS' 1 3 1 1.00 2 0.00 3 1.00
'SS' 2 3 4 1.00 6 1.00 7 2.00
'SS' 3 1 5 1.00
'D←SCALE' 0.019
'SPEED' 10.0
'TX'
'SCM'
'CAP'
'SERVTM' 25.0
'RUN' 2.88 0.00
```

<u>Figure VI-8</u>

SAMPLE PRINTOUT ILLUSTRATING THE USE OF THE "NEWPLAN" COMMAND

```
12.05.02 >MODPLAN
ENTER NAME OF DISTRICT PLAN FILE TO BE CHANGED>SAMPLAN1
EDIT:
>LOCATE $SCM$
'SCM'
>REPLACE 'MCM'
>PRINT
'MCM'
>L $RUN$
'RUN' 2.88 0.00
>R 'RUN' 3.88 1.00
>PRINT
'RUN' 3.88 1.00
>TOP
>L $NUM$
M=3 R=7 NUM=1 ESTSTAT=1;
>REPLACE M=3 R=7 NUM=2 ESTSTAT=1;
>LOCATE $MCM$
'MCM'
>INSERT 'ALLOCATE'
>FILE
DO YOU WANT SAMPLAN1 LISTED?>Y

M=3 R=7 NUM=2 ESTSTAT=1;
'TITLE' 'SAMPLE 3-CAR RUN WITH 7 REPORTING AREAS'
'PRNT←CFS'
'ATOM←NO'
'LAM'
'SS' 1 3 1 1.00 2 0.00 3 1.00
'SS' 2 3 4 1.00 6 1.00 7 2.00
'SS' 3 1 5 1.00
'D←SCALE' 0.019
'SPEED' 10.0
'TX'
'MCM'
'ALLOCATE'
'CAP'
'SERVTM' 25.0
'RUN' 3.88 1.00
```

Figure VI-9

SAMPLE PRINTOUT ILLUSTRATING THE USE OF THE "MODPLAN" COMMAND

VII. Computing Performance Measures

Once the region and district plan files have been created for the jurisdiction of interest, the hypercube program is used to compute the expected performance measures associated with the district plan. This program can be used "on-line," or on a delayed or "batch" basis. When used on-line, calculations are performed and tables are formatted while the user is logged on to the NCSS system. Results are available immediately. When used in a batch mode, the calculations are not performed until after the user has logged off of the system -- usually in the late evening or early morning hours. Consequently, the output is not available until the next day. On the other hand, the cost of using the hypercube program on-line is approximately 2.5 times the cost of batch usage.

Before invoking the hypercube program, the user must determine the amount of core storage that will be required. This amount will depend on the number of reporting areas in the region, the number of districts specified in the district plan, the number of workload levels for which performance measures are to be computed, the hypercube model to be used (exact or approximate), and the dispatch policy (AVL or non-AVL). Figure D-4 shows the amount of core storage required to use the approximate hypercube model for varying numbers of reporting areas and districts. Figure D-5 shows the amount of core storage required to use the exact hypercube model with a non-AVL dispatch policy. Figure D-6 shows the amount of core storage required to use the exact hypercube model with AVL dispatching. These figures show the core storage required when performance measures are computed at only one workload level. For the approximate model, the tabular values must be increased by one for each three additional workload levels specified. When the exact model is used with a non-AVL dispatching policy, the value shown in Figure D-5 must be increased by the incremental amount shown in Figure D-7 for each additional workload level specified. When the exact model is used with the AVL dispatching policy, the value shown in Figure D-6 must be increased by the incremental amount shown in Figure D-8 for each additional workload level specified.

The commands used to invoke the hypercube program are discussed below. In addition, users are given the opportunity to use the hypercube program whenever they create a new district plan file using either the "MONITNEW" or "MONITOLD" command. Thus, the user is asked

DO YOU WANT TO COMPUTE PERFORMANCE MEASURES AT THIS TIME?

If the user replies affirmatively, the hypercube program is executed on-line. (Note that this can be done only if the hypercube program requires no more core storage than the monitor program was using.) Otherwise, the user is asked

DO YOU WANT TO COMPUTE PERFORMANCE MEASURES OVERNIGHT?

An affirmative response means that the hypercube program will be executed in the batch mode. If the user indicates that he does not want the performance measures computed either "at this time" or "overnight," then the "MONITNEW" (or "MONITOLD") command is terminated and the hypercube program will have to be invoked using the commands described below.

1. "HYPERCUBE" command– the "HYPERCUBE" command is used to execute the hypercube program on-line. Prior to using this command, the "SET CORE" command (see Chapter VI) is used to specify the amount of core storage required. After the "HYPERCUBE" command has been entered, the user is prompted for the names of the region and district plan files. Once this information has been entered, the user can choose to have the output produced by the hypercube program printed at his terminal as it is generated, or stored in a file on disk for later retrieval. In the latter case, the user must ensure that sufficient disk storage is available for the output file, before using the "HYPERCUBE" command. This is done as follows:

   a. Determine the total number of lines of output to be produced by summing the number of lines in the individual tables requested in the district plan file (see Table VII-1).

   b. Enter the command

      STAT P

      The computer should respond

      P-DSK (WT): records USED, records LEFT (OF total-records), percent (OF number CYL)

   c. Multiply the number of records left by 10. If the result does not exceed the total number of lines of output by at least 20 times the number of CYLs, then the disk storage space is insufficient to contain the output file. In this case, files must be deleted, available disk storage must be increased, or the hypercube output must be listed as it is generated rather than being stored for later retrieval.

   If the user chooses to have the output stored, he is prompted for the name to be given to the output file. When all information has been entered, the computer should respond

      EXECUTION:

      output file CONTAINS THE OUTPUT TABLES
      termination messages
      CORE RESET TO 256

   if the output was stored, or

      EXECUTION:

      hypercube output
      CORE RESET TO 256

Table VII-1

LINES OF OUTPUT PRODUCED IN INDIVIDUAL HYPERCUBE TABLES

HYPERCUBE OUTPUT TABLE	LINES OF OUTPUT*
1. Calls for service	$R + 1$
2. Estimated dispatch costs	$\lceil M/8 \rceil \times (R + 2) + 8$
3. Patrolled street miles	$R + 1$
4. Preventive patrol coverage	$\lceil M/8 \rceil \times (R + 2) + 3$
5. Unit to reporting area travel times	$\lceil M/8 \rceil \times (R + 2) + 5$
6. Inter-reporting area travel times	$\lceil R/7 \rceil \times (R + 2) + 1$
7. Variable service times	$M + 1$
8. Region, unit, and district performance measures	$N \times (2 \times M + 35)$
9. Atom specific performance measures when a non-AVL dispatching policy is used	$\{\lceil M/9 \rceil \times (R + 1) + R + 11\} \times N$
10. Atom specific performance measures when AVL dispatching is used	$\{\lceil M/9 \rceil \times (R + 1) + \lceil M/8 \rceil \times (R + 2) + R + 15\} \times N$

*R = number of reporting areas, M = number of districts, N = number of workload levels, and $\lceil x \rceil$ denotes the smallest integer number equal to or greater than x.

if the output was not stored. "Termination messages" are the last two lines of hypercube output. If an error occurred, these messages will indicate the cause. Successful program completion is indicated when the message printed is "ALL DONE." Figure VII-1 illustrates the use of the "HYPERCUBE" command.

2. "OVERNITE" command - The "OVERNITE" command is used to execute the hypercube program in batch mode. Since output must be stored when the "OVERNITE" command is used, the user must ensure that sufficient disk storage space is available as described above. After the command has been entered, the user is prompted for the names of the region, district plan, and output files, for the amount of core storage* required by the hypercube program to compute its output measures, and for his password. Once this information has been entered, the computer should respond

   BATCH JOB WILL BE RUN

   or by printing the time-of-day. Both responses indicate that the hypercube program has been scheduled for overnight execution. Figure VII-2 illustrates the use of the "OVERNITE" command.

3. "CANCEL" command - the "CANCEL" command is used to cancel all previously scheduled overnight executions of the hypercube program. The computer should respond as shown in Figure VII-3. Successful cancellation is indicated when the status listed is "DELETED."

The alternative procedures for computing performance measures are illustrated in Figure E-4.

---

*Note that if the hypercube program is to be run more than once on the same night, the core storage specification should reflect the largest district plan to be analyzed. Also, the combined sizes of all resulting output files must be considered in determining the sufficiency of available disk storage.

```
12.36.12 >HYPERCUBE
ENTER NAME OF REGION FILE (I.E., THE NAME OF THE FILE THAT
CONTAINS GEOGRAPHIC AND CALL VOLUME DATA FOR EACH REPORTING
AREA IN THE REGION OF INTEREST)>SAMCITY
ENTER NAME OF DISTRICT PLAN (I.E., THE NAME GIVEN TO THE DISTRICT
PLAN CREATED USING THE MONITNEW, MONITOLD, NEWPLAN, OR
MODPLAN COMMAND)>SAMPLAN2
ALL OUTPUT REQUESTED IN SAMPLAN2 CAN BE PRINTED AT YOUR TERMINAL
AS IT IS GENERATED BY THE HYPERCUBE PROGRAM, OR IT CAN BE
STORED FOR LATER RETRIEVAL. DO YOU WANT THE OUTPUT STORED?>Y
ENTER NAME OF FILE THAT WILL CONTAIN THE OUTPUT TABLES>OUTPLAN2
EXECUTION:

 $$OUTPLAN2 CONTAINS THE OUTPUT TABLES

      7      6.84      1.03      2.28
 ALL DONE


 CORE RESET TO 256
```

Figure VII-1

SAMPLE PRINTOUT ILLUSTRATING THE USE OF THE "HYPERCUBE" COMMAND

```
15.03.06 >OVERNITE
ENTER NAME OF REGION FILE (I.E., THE NAME OF THE FILE THAT
CONTAINS GEOGRAPHIC AND CALL VOLUME DATA FOR EACH REPORTING
AREA IN THE REGION OF INTEREST)>SAMCITY
ENTER NAME OF DISTRICT PLAN (I.E., THE NAME GIVEN TO THE DISTRICT
PLAN CREATED USING THE MONITNEW, MONITOLD, NEWPLAN, OR MODPLAN
COMMAND)>SAMPLAN2
ENTER NAME OF FILE THAT WILL CONTAIN THE OUTPUT TABLES>OUTPLAN2
ENTER CORE STORAGE REQUIRED TO COMPUTE THE OUTPUT MEASURES
(I.E., THE VALUE YOU SPECIFY IN THE "SET CORE" COMMAND
BEFORE US,NG THE "HYPERCUBE" COMMAND)>256
ENTER PASSWORD:
[redacted]

BATCH JOB WILL BE RUN.
```

Figure VII-2

SAMPLE PRINTOUT ILLUSTRATING THE USE OF THE "OVERNITE" COMMAND

```
11.15.25 >CANCEL

11.15.38
USERID        ACINFO          SUBDATE   SUB/OFF   EST IO      EST ARU
STATUS   PR                   RUNDATE   TIME ON               ARU USED

TIPPA    MANUAL               07/28/77  11.15.38   15000        600.00
DELETED   2
```

Figure VII-3

SAMPLE PRINTOUT ILLUSTRATING THE USE OF THE "CANCEL" COMMAND

VIII. Retrieving and Interpreting Hypercube Output

1. Retrieving Stored Output

Hypercube output that has been stored in an output file is retrieved using the following commands:

a. "LISTALL" command - The "LISTALL" command is used to list all hypercube output that was produced as a result of user specifications in the district plan file. The "LISTALL" command should be used sparingly when the output file is large because of the time required to list it on a low speed terminal. For example, if an output file contains n lines (determined using the "LISTF" command described in Chapter V) with an average length of 60 characters, then approximately n/30 minutes are required to list the entire file at a terminal operating speed of 30 characters per second. When the command is used, the user is prompted for the name of the output file.

b. "LISTHYP" command - The "LISTHYP" command is used to obtain a listing of only selected tables in the output file. After the command has been entered, the computer prompts the user for the name of the output file, the number of reporting areas in the region, and the numbers of districts and workload levels specified in the district plan. After this information has been entered, the computer prompts the user to indicate whether or not the following tables are to be listed:

(1) All output (equivalent to using the "LISTALL" command).

(2) Relative incident rates (see Figure VIII-3).

(3) Patrolled street miles (see Figure VIII-4).

(4) Variable service times (see Figure VIII-12).

(5) Inter-reporting area travel times (see Figure VIII-5).

(6) Mean travel times (see Figure VIII-6).

(7) Dispatch costs (see Figure VIII-7).

(8) Relative patrol rates (see Figure VIII-8).

(9) Region, unit, and district output measures (See Figure VIII-9).

(10) Output measures for each reporting area (see Figure VIII-10 and VIII-11).

After this information has been entered, the computer will print those tables found in the output file which the user wants listed. Requests to list tables that were not produced by the hypercube program are ignored. Figure VIII-1 illustrates the use of the "LISTHYP" command.

c. "BRFLIST" command - The BRFLIST" command is used to obtain an abbreviated listing of hypercube output consisting of only the region, unit, district, and (if generated) reporting area specific performance measures. After the command is entered, the computer prompts the user for the name of the output file. When this information has been supplied, the computer prints the appropriate tables.

d. "VERYBRF" command - The "VERYBRF" command is identical to the "BRFLIST" command in both function and usage except that only the region, unit, and district specific performance measures are listed, and the user is also prompted for the numbers of units and workload levels specified in the district plan.

e. "CONLIST" command - The "CONLIST" command is used to list the terminal console log associated with batch executions of the hypercube program. A single console log is produced for all batch runs made the same night, regardless of how many times the hypercube program is used. This log should be listed since it will contain error messages, as well as data from which the cost of the overnight runs can be determined. To compute the cost, multiply the number of ARU's shown near the bottom of the log by $0.08. If the computer responds to the "CONLIST" command with the message

NO CARDS TO BE READ

no console log was produced (probably because no batch processing was done).

When output files are large, it may be necessary to increase core storage using the "SET CORE" command discussed in Chapter VI before using the "LISTHYP", "BRFLIST", or "VERYBRF" commands

```
12.00.55 >LISTHYP
ENTER NAME OF FILE THAT CONTAINS THE OUTPUT TABLES>OUTPLAN2
ENTER NUMBER OF REPORTING AREAS>7
ENTER NUMBER OF UNITS>3
ENTER NUMBER OF WORKLOAD LEVELS>1

DO YOU WANT ALL OUTPUT LISTED?>N

DO YOU WANT THE RELATIVE INCIDENT RATES LISTED?>N

DO YOU WANT PATROL STREET MILES LISTED?>N

DO YOU WANT VARIABLE SERVICE TIMES LISTED?>Y

DO YOU WANT INTER-REPORTING AREA TRAVEL TIMES LISTED?>N

DO YOU WANT MEAN TRAVEL TIMES LISTED?>N

DO YOU WANT DISPATCH COSTS LISTED?>N

DO YOU WANT RELATIVE PATROL RATES LISTED?>N

DO YOU WANT THE REGION, UNIT, AND DISTRICT OUTPUT
MEASURES LISTED?>N

DO YOU WANT THE OUTPUT MEASURES LISTED FOR
EACH REPORTING AREA?>N


SERVICE TIME FOR EACH RESPONSE+UNIT
    UNIT        1      20.00 MINUTES
    UNIT        2      25.00 MINUTES
    UNIT        3      30.00 MINUTES
```

Figure VIII-1

SAMPLE PRINTOUT ILLUSTRATING THE USE OF THE "LISTHYP" COMMAND

even if only a small part of the output is being listed. Figure D-9 shows the approximate amount of core storage required to use these commands to list portions of output files containing various numbers of lines. (If sufficient core storage is not available when the "LISTHYP", "BRFLIST", or "VERYBRF" commands are used, the message

```
FILE TOO LARGE TO EDIT, SET CORE TO LARGER VALUE
!!E(00020)!!
```

is printed.)

Figure E-5 illustrates the procedures for retrieving stored hypercube output.

2. Interpreting Hypercube Output

In the report, "Hypercube Queuing Model: User's Manual," Chapter 3 is devoted to a simple example of the output generated by the hypercube programs. The following discussion is based on a slightly modified version of that material. Figure VIII-2 shows the region for which the sample analysis was made. Three cars patrol a total of seven reporting areas. The run was titled "Sample 3-Car Run with 7 Reporting Areas." For each reporting area, the input call rates, district car assignments, and preventive patrol factors were:

Reporting Area	Call Rates	Car Assigned			Prev. Pat. Factor
		1	2	3	
1	1000	x			1.0
2	1000	x			0.0
3	1000	x			1.0
4	1000		x		1.0
5	2000			x	1.0
6	1000		x		1.0
7	1000		x		2.0

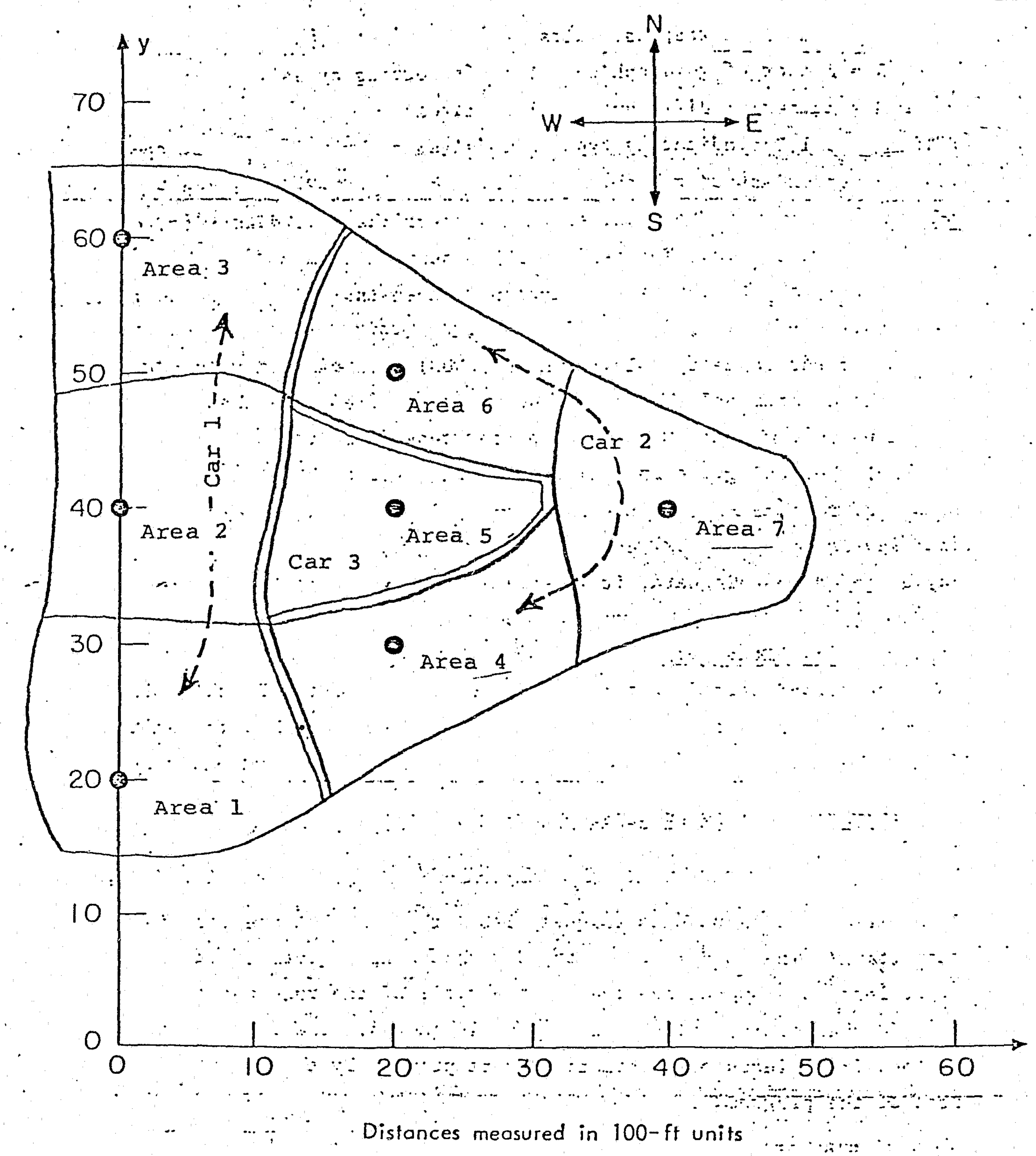

Figure VIII-2

THREE CARS PATROLLING SEVEN REPORTING AREAS IN REGION OF SAMPLE ANALYSIS

Values of other input variables were:

Response speed - 10 m.p.h.
Dispatch policy - SCM
Queue capacity - queue calls at dispatcher
Service time - 25 minutes
Call arrival rate - 2.88 calls/hour
Patrol speed - 5 m.p.h.

Use of the above information as input to the hypercube program produced the output described below, which is discussed table by table or line by line, as appropriate.

The first output table, shown in Figure VIII-3, contains the distribution of calls for service by reporting area. Examination of this table reveals that 25 percent of the calls originate in area 5, while each of the other six areas generate 12.5 percent of the calls.

The table illustrated in Figure VIII-4 shows the number of patrolled street miles in each reporting area. For example, area 2 contains 3.46 patrolled street miles. Note that this table cannot be produced unless a patrol speed is specified in the district plan file, and the numbers of street miles are specified in the region file.

Figure VIII-5 illustrates the table showing inter-reporting area travel times in minutes. For example, the travel time from area 4 to area 6 is 2.28 minutes. All travel times in this table were computed using the manhattan metric since no travel time estimates were input directly in the district plan file by the user.

---

*Since no "glossary" was provided, the default glossary was used in producing the output (e.g., the term "ATOM" is used to refer to reporting areas).

CALLS FOR SERVICE DISTRIBUTION, BY ATOM	
1	0.12500
2	0.12500
3	0.12500
4	0.12500
5	0.25000
6	0.12500
7	0.12500

Figure VIII-3

HYPERCUBE OUTPUT SHOWING THE CALLS FOR SERVICE DISTRIBUTION BY REPORTING AREA

PATROL STREET MILES PER ATOM	
1	4.11
2	3.46
3	3.62
4	2.90
5	2.50
6	2.66
7	3.36

Figure VIII-4

HYPERCUBE OUTPUT SHOWING PATROLLED STREET MILES BY REPORTING AREA

TRAVEL TIME MATRIX: INTER-ATOM

ATOM NUMBER: ORIGIN	ATOM NUMBER: DESTINATION 1	2	3	4	5	6	7
1	0.00	2.28	4.56	3.42	4.56	5.70	6.84
2	2.28	0.00	2.28	3.42	2.28	3.42	4.56
3	4.56	2.28	0.00	5.70	4.56	3.42	6.84
4	3.42	3.42	5.70	0.00	1.14	2.28	3.42
5	4.56	2.28	4.56	1.14	0.00	1.14	2.28
6	5.70	3.42	3.42	2.28	1.14	0.00	3.42
7	6.84	4.56	6.84	3.42	2.28	3.42	0.00

Figure VIII-5

HYPERCUBE OUTPUT SHOWING INTER-REPORTING AREA TRAVEL TIMES

MEAN TRAVEL TIMES FOR EACH RESPONSE+UNIT TO EACH ATOM

ATOM ID NO	ID OF RESPONSE+UNIT: UNIT 1	UNIT 2	UNIT 3
1	2.28	5.70	4.56
2	2.28	3.99	2.28
3	2.28	5.70	4.56
4	4.56	2.28	1.14
5	4.56	1.71	0.00
6	4.56	2.28	1.14
7	6.84	1.71	2.28

Figure VIII-6

HYPERCUBE OUTPUT SHOWING MEAN TRAVEL TIMES FOR EACH UNIT TO EACH REPORTING AREA

Note that intra-reporting area travel times are zero because no proportionality constant (i.e., CORTM) was specified in the district plan file.

Mean times required for each unit (while positioned in its own district) to travel to each reporting area are displayed in a table such as that shown in Figure VIII-6. For example, the mean time required for unit 2 to travel to area 3 is 5.70 minutes.

The next part of the output, shown in Figure VIII-7, indicates that the SCM (strict center of mass) dispatch policy was selected by the user, and presents the estimated "cost" -- the travel time as estimated by the dispatcher -- associated with dispatching each of the units to each of the reporting areas. Considering the information displayed for any reporting area, it is an easy matter to rank the cars in terms of how rapidly each could respond to a call in that area, and to use this ranking to determine which available unit to dispatch to a call. This ranking of cars for each reporting area is performed automatically by the hypercube programs, and is then utilized in computing the remaining output values. Interpreting the dispatch costs as travel times, Figure VIII-7 indicates that the dispatcher estimates that unit 1 requires 3.04 minutes to travel to a call in area 4, whereas units 2 and 3 require 0.38 and 0.76 minutes, respectively. Thus, the dispatcher would assign unit 2 to a call in area 4 if that unit were available. Otherwise, he would prefer to dispatch unit 3. Unit 1 would be dispatched to calls in area 4 only if the other two units were unavailable. By modifying the entries in this

```
STRICT CENTER-OF-MASS DISPATCHING
ESTIMATED "COST" OF DISPATCHING I-TH RESPONSE+UNIT
     TO J-TH ATOM
ATOM              ID OF RESPONSE+UNIT
ID
NO             UNIT      UNIT      UNIT
                  1         2         3

      1        0.00      3.42      2.28
      2        0.00      3.42      2.28
      3        0.00      3.42      2.28
      4        3.04      0.38      0.76
      5        2.28      1.14      0.00
      6        3.04      0.38      0.76
      7        3.04      0.38      0.76
```

Figure VIII-7

HYPERCUBE OUTPUT SHOWING ESTIMATED COST OF DISPATCHING EACH UNIT TO EACH REPORTING AREA

```
    RESPONSE+UNIT          SPATIAL ALLOCATION, WHILE AVAILABLE
ATOM              ID OF RESPONSE+UNIT
NO.            UNIT      UNIT      UNIT
                  1         2         3

     1         0.50      0.00      0.00
     2        -0.50      0.00      0.00
     3         0.50      0.00      0.00
     4         0.00      0.25      0.00
     5         0.00      0.00      1.00
     6         0.00      0.25      0.00
     7         0.00      0.50      0.00
```

Figure VIII-8

HYPERCUBE OUTPUT SHOWING THE DISTRIBUTION OF EACH UNIT'S PREVENTIVE PATROL TIME AMONG THE REPORTING AREAS table, users can specify an arbitrary fixed preference dispatch policy. This table is not produced if AVL dispatching is used.

The output table illustrated in Figure VIII-8 indicates the fraction of available (i.e., preventive patrol) time that each unit spends in each of the reporting areas. These fractions are computed using the preventive patrol factors specified in the district plan file. An entry with a minus (-) allocation implies that the corresponding patrol unit spends no patrol time there, but that the area is "contained" in that unit's district. (The question of areas belonging to districts is important when considering dispatch policies.) From Figure VIII-8 it is seen that unit 2 spends 50 percent of its available time in area 7 and 25 percent in each of areas 4 and 6. Unit 3 spends all of its time in area 5. Unit 1 splits its time equally between areas 1 and 3, but still considers area 2 to be in its district.

The next output table contains the computed region, unit, and district performance measures as shown in Figure VIII-9. Individual lines of output are interpreted as follows:

```
PROBLEM TITLE:  SAMPLE 3-CAR RUN WITH 7 REPORTING AREAS.
```

This line is self-explanatory. The title printed is supplied by the user in the district plan file.

```
***ITERATIVE APPROXIMATION METHOD USED***
NUMBER OF ITERATIONS REQUIRED:  3
```

The district plan file specified that the calculations were to be made using the hypercube program's approximation procedures. These

```
PROBLEM TITLE: SAMPLE 3-CAR RUN WITH 7 REPORTING AREAS
    * ITERATIVE APPROXIMATION METHOD USED *
    NUMBER OF ITERATIONS REQUIRED:          3
UNLIMITED CAPACITY QUEUE WITH 1+ST-COME 1+ST-SERVED QUEUE DISCIPLINE
RUN NUMBER:  1
RESPONSE+UNIT         ...TOTAL NUMBER OF =  3
ATOM       ...TOTAL NUMBER OF =   7
AVERAGE SERVICE TIME=  25.00 MINUTES
AVERAGE NUMBER PER HOUR OF CALLS FOR SERVICE  =   2.880
AVERAGE NUMBER PER  25.00 MINUTES OF CALLS FOR SERVICE  =   1.200
SPEED OF PATROL=   5.00 MPH
AVERAGE UTILIZATION FACTOR
   (IN THE CASE OF UNLIMITED LINE CAPACITY)=  0.400
REGION-WIDE AVERAGE TRAVEL TIME=   2.209 MINUTES
AVERAGE TRAVEL TIME FOR QUEUED CALLS=   2.921 MINUTES
PROBABILITY OF SATURATION= 0.14118
REGION-WIDE AVERAGE WORKLOAD (% TIME BUSY)= 0.40000
STANDARD DEVIATION OF WORKLOAD=   0.010
MAXIMUM WORKLOAD IMBALANCE= 0.02019
FRACTION OF DISPATCHES THAT ARE INTER-DISTRICT = 0.35255
REGION-WIDE AVERAGE PATROL FREQUENCY=    0.519 PASSES PER HOUR
PERFORMANCE MEASURES THAT ARE SPECIFIC TO EACH RESPONSE+UNIT
```

ID OF RESPONSE+UNIT NAME	NO	WORKLOAD OF UNIT	% OF MEAN	FRACTION OF DISPATCHES OUT OF DISTRICT	% OF MEAN	AVERAGE TRAVEL TIME
UNIT	1	0.388	97.1	.2351	66.7	2.768
UNIT	2	0.409	102.1	.2975	84.4	2.378
UNIT	3	0.403	100.8	.5209	147.8	1.501

PERFORMANCE MEASURES THAT ARE SPECIFIC TO EACH DISTRICT

ID OF DISTRICT NAME	NO	WORKLOAD OF DISTRICT	% OF MEAN	FRACTION OF DISPATCHES INTER-DISTRICT	% OF MEAN	AVERAGE TRAVEL TIME
DIST	1	0.450	112.5	.3418	97.0	2.920
DIST	2	0.450	112.5	.3609	102.4	2.342
DIST	3	0.300	75.0	.3556	100.9	0.940

Figure VIII-9

HYPERCUBE OUTPUT SHOWING REGION, UNIT, AND DISTRICT PERFORMANCE MEASURES involve successive improvement of approximate values in sets of repeated calculations called "iterations." The above lines of output, mainly useful to mathematicians, indicate the number of sets of calculations required.

UNLIMITED CAPACITY QUEUE WITH 1-ST-COME 1-ST-SERVED QUEUE DISCIPLINE

This indicates that calls-for-service arriving when all patrol units are busy are entered into a dispatcher's queue which is depleted or serviced in a first-come, first-served manner.

RUN NUMBER: 1

This states that the current table corresponds to workload level 1. When the user asks for more than one run by specifying more than one workload level, similar tables are produced corresponding to different arrival rates of calls for service.

RESPONSE UNIT ... TOTAL NUMBER OF = 3
ATOM ... TOTAL NUMBER OF = 7

These lines are self-explanatory.

SPEED OF PATROL = 5.00 M.P.H.

This line confirms the patrol speed specified in the district plan file. It is not printed unless a patrol speed was specified.

AVERAGE SERVICE TIME = 25.00 MINUTES

This indicates the average service time specified in the district plan file.

AVERAGE NUMBER PER HOUR OF CALLS FOR SERVICE = 2.880
AVERAGE NUMBER PER 25.00 MINUTES OF CALLS FOR SERVICE = 1.200

Since there are an average of 2.88 calls for service generated per hour, there are an average of 2.88 x (25/60) = 1.200 calls for service generated each 25 minutes. With dispatcher queues allowed, this is important for the following reason: if there was only one unit to handle this workload, then an average of 1.200 incidents would arrive during the time required (on average) to service one incident. Thus, one unit would not be able to handle this workload. However, two (or more) could do the job without having backlogs of calls build up indefinitely. If this figure had been 2.200 instead of 1.200, then at least three units would have been required to handle the workload. In general, whatever this figure is, the next highest integer is the minimum number of response units required to do the job. If the user attempts to run the model with too few response units (assuming dispatcher queues are allowed), then the run stops and the error message "QUEUE SATURATED" is printed. When backup service is utilized instead of queues, the user can operate the model with any number of patrol units. However, if this number is too small (in comparison to the workload generated per hour), then a large fraction of calls will be handled by the backup response system and only a small fraction will be covered by the district cars.

AVERAGE UTILIZATION FACTOR
(IN THE CASE OF UNLIMITED LINE CAPACITY) = 0.400

Since 1.200 calls arrive on the average each 25 minutes, and all (eventually) are assigned to a car, then on the average 1.200 x (1/3) = 0.400 incidents are assigned to any particular district car every 25 minutes. But each such assignment requires (on average) 25 minutes to service, thus the "average beat car" is busy servicing incidents 40.0 percent of the time. This figure is called the average utilization factor (referring to the fraction or percent of time that district cars are servicing incidents). Reflecting on the discussion above, this utilization factor must be less than 1.0 for the case when dispatcher's queues are allowed.

All of the output to this point mainly restates input data. The remaining lines give values for various field performance measures, as computed by the model.

REGION-WIDE AVERAGE TRAVEL TIME = 2.209 MINUTES

This indicates that the average travel time to a service incident, averaged over all the reporting areas in the region, is 2.209 minutes. Since the travel speed is 10 mph (or 1/6 mile per minute), this implies that the average distance traveled per response is (1/6) x (2.209) = 0.368 miles, a figure that is intuitively reasonable. (The entire region in this example is 4000 feet or 0.76 miles east-west and north-south.)

AVERAGE TRAVEL TIME FOR QUEUED CALLS = 2.921 MINUTES

Here the program is showing the somewhat larger average travel time incurred by incidents that are delayed in a dispatcher's queue (averaged over all incidents delayed in queue, regardless of reporting area). Of course, in application, a travel time of 2, 3, or 5 minutes may be insignificant compared to a queue delay time of 15, 30, or 60 minutes. (Queue delay times are not computed by the hypercube program, but a simple formula for computing them is given later in this chapter.)

PROBABILITY OF SATURATION = 0.14118

"Saturation" is said to occur when all patrol units are simultaneously busy handling calls for service. If this occurs X percent of the time, then (due to the random arrival patterns of service incidents) X percent of the calls reach a "saturated system" and thus must be held in the dispatcher queue. In this case, 14.118 percent of all calls for service are held in queue. (In the case of backup service when all cars are busy X percent of the time, this percent of all calls are transferred to the backup units.)

REGION-WIDE AVERAGE WORKLOAD (% TIME BUSY) = 0.40000

This is the average fraction of time that cars are busy handling service incidents. When dispatcher queues are allowed, this figure will equal (within acceptable round-off error) the average utilization factor discussed earlier. In the case of backup service, the region-wide workload will be somewhat less than the utilization factor, due to overflow incidents being assigned to backup units.

STANDARD DEVIATION OF WORKLOAD = 0.010

This is the standard deviation of the district car workloads (compared to the average car workload) which measures the imbalance in workloads among cars. The larger this quantity is the greater is the imbalance. If this quantity is zero, then the workloads of all cars are equal.

MAXIMUM WORKLOAD IMBALANCE = 0.02019

Subtracting the workload of the least busy car (car 1 in this case) from the workload of the busiest car (car 2) gives the maximum workload imbalance. (In this case the maximum workload imbalance is 0.409 - 0.388 = 0.021, which, within error tolerances, is the same as 0.02019.)

FRACTION OF DISPATCHES THAT ARE INTER-DISTRICT = 0.35255

This indicates that 35.255 percent of all dispatch assignments (including those from a queue of calls) cause the assigned unit to travel to a reporting area not in its own district. Thus, for a randomly selected call for service, there is a 35.255 percent chance that the car which responds will not be a car whose district contains the incident.

REGION_WIDE AVERAGE PATROL FREQUENCY = 0.519 PASSES PER HOUR

This says that the average number of times per hour a random point in the region is passed by a unit on preventive patrol is 0.519 (i.e., a patrol unit passes the point once every (1/0.519) = 1.93 hours on the average). This line is not printed unless a patrol speed is specified in the district plan.

The next eight lines in the table contain unit-specific performance measures. Examining the performance measures for unit 1 (identified in the leftmost column in this portion of the output), we see the following (reading from left to right):

- Unit 1 spends 38.8 percent of its time handling service incidents.
- Its workload is 97.1 percent of the average workload of all three units (which is 40.0 percent).
- 23.51 percent of the dispatch assignments to this car cause it to leave its district.
- This cross-district dispatch frequency is 66.7 percent of the mean for the three cars (which is 35.255 percent).
- The average time taken by unit 1 to travel to the scene of an incident is 2.768 minutes. Similar interpretations apply to units 2 and 3.

The last eight lines of the table contain the district-specific performance measures. For district 1, we see the following (reading from left to right):

- The district's workload would cause one unit to remain busy servicing calls 45.0 percent of the time if that car handled all of district 1's calls and no others.
- This workload is 12.5 percent above the mean for the three districts.
- 34.18 percent of the district's incidents require an out-of-district car (either car 2 or 3) because car 1 is unavailable.

- o The average travel time for calls for service in district 1 is 2.920 minutes.

Similar interpretations apply to districts 2 and 3.

The final two output tables shown in Figures VIII-10 and VIII-11 contain performance measures that are specific to each reporting area. For area 1, for example, we see the following:

- o The area generates an average of 36.00 calls per 100 hours (Figure VIII-10).
- o The average travel time to incidents in the area is 3.163 minutes. (Figure VIII-10).
- o A random point in area 1 is passed an average of 0.37 times per hour by a unit on preventive patrol. (This column appears in the table only if a patrol speed is specified in the district plan file.)
- o Sixty-six percent of all calls from the area are handled by car 1, 11 percent by car 2, and 23 percent by car 3 (Figure VIII-11).

Judicious examination of the travel time estimates in these tables will allow the user to spot inequities in the distribution of service accessibility to reporting areas.

The above tables represent all the output that is produced using the district plan file input for this example. If individual service times had been specified for each response unit, a table such as that illustrated in Figure VIII-12 could have been requested. It summarizes the service times the user has specified for each response unit in the district plan file.

PERFORMANCE MEASURES THAT ARE SPECIFIC TO EACH ATOM ID # ATOM	WORKLOAD OF ATOM (#CALLS/100HR)	AVERAGE TRAVEL TIME	FREQUENCY OF PREVENTIVE PATROL PASSINGS (#/HOUR)
1	36.00	3.163	0.37
2	36.00	2.435	0.00
3	36.00	3.163	0.42
4	36.00	2.271	0.25
5	72.00	0.940	1.19
6	36.00	2.271	0.28
7	36.00	2.464	0.44

Figure VIII-10

HYPERCUBE OUTPUT SHOWING UNIT-INDEPENDENT PERFORMANCE MEASURES SPECIFIC TO EACH REPORTING AREA

PERFORMANCE MEASURES THAT ARE SPECIFIC TO EACH ATOM

ID # ATOM	FRACTION OF CALLS FOR SERVICE FROM ATOM SERVICED BY UNIT NUMBER: 1	2	3
1	0.66	0.11	0.23
2	0.66	0.11	0.23
3	0.66	0.11	0.23
4	0.12	0.64	0.24
5	0.12	0.23	0.64
6	0.12	0.64	0.24
7	0.12	0.64	0.24

Figure VIII-11

HYPERCUBE OUTPUT SHOWING THE FRACTION OF CALLS IN EACH REPORTING AREA SERVICED BY EACH RESPONSE UNIT

SERVICE TIME FOR EACH RESPONSE+UNIT

UNIT	1	20.00 MINUTES
UNIT	2	25.00 MINUTES
UNIT	3	30.00 MINUTES

Figure VIII-12

HYPERCUBE OUTPUT SHOWING VARIABLE SERVICE TIMES BY UNIT

Figures VIII-13 through VIII-16 illustrate the tables of performance measures produced when AVL dispatching is specified using the "COMPARE" instruction. Comparison of Figures VIII-13 and VIII-9 reveal the following differences:

- The lines

  *** ITERATIVE APPROXIMATION METHOD USED ***
  NUMBER OF ITERATIONS REQUIRED: 3

  are not printed since the exact hypercube model is automatically used when AVL dispatching is specified.

- The line

  IN-QUEUE TRAVEL TIMES ONLY APPROXIMATE DUE TO UNEQUAL SERVICE TIMES.

  is printed to alert the user to a hypercube approximation necessitated by user specified variable service times.

- The line

  TOTAL PROBABILITY OF ERROR WITH SCM = 0.16985

  is printed, indicating that a car other than the closest one available will be assigned for 16.985 percent of the dispatches when the SCM dispatch policy is used. This also equals the fraction of calls for which AVL dispatching would produce quicker response.

In Figure VIII-14 (which is analogous to Figure VIII-10), an additional column is printed showing the dispatch error probability (of SCM compared to AVL dispatching) for calls occurring in each reporting area. For example, 15.67 percent of all calls in area 1 would be serviced by other than the closest available unit.

The interpretation of Figure VIII-15 is identical to that of Figure VIII-11.

STRICT CENTER-OF-MASS DISPATCHING
PROBLEM TITLE: SAMPLE 3-CAR RUN WITH 7 REPORTING AREAS
UNLIMITED CAPACITY QUEUE WITH 1÷ST-COME 1÷SI-SERVED QUEUE DISCIPLINE
IN-QUEUE TRAVEL TIMES ONLY APPROXIMATE DUE TO UNEQUAL SERVICE TIMES
RUN NUMBER: 1
RESPONSE÷UNIT ...TOTAL NUMBER OF = 3
ATOM ...TOTAL NUMBER OF = 7
AVERAGE SERVICE TIME= 24.32 MINUTES
AVERAGE NUMBER PER HOUR OF CALLS FOR SERVICE = 2.880
AVERAGE NUMBER PER 24.32 MINUTES OF CALLS FOR SERVICE = 1.168
SPEED OF PATROL= 5.00 MPH
TOTAL PROBABILITY OF ERROR WITH SCM = 0.16985
AVERAGE UTILIZATION FACTOR
(IN THE CASE OF UNLIMITED LINE CAPACITY)= 0.389
REGION-WIDE AVERAGE TRAVEL TIME= 2.107 MINUTES
AVERAGE TRAVEL TIME FOR QUEUED CALLS= 2.921 MINUTES
PROBABILITY OF SATURATION= 0.13227
REGION-WIDE AVERAGE WORKLOAD (% TIME BUSY)= 0.39942
STANDARD DEVIATION OF WORKLOAD= 0.103
MAXIMUM WORKLOAD IMBALANCE= 0.19277
FRACTION OF DISPATCHES THAT ARE INTER-DISTRICT = 0.48774
REGION-WIDE AVERAGE PATROL FREQUENCY= 0.483 PASSES PER HOUR
PERFORMANCE MEASURES THAT ARE SPECIFIC TO EACH RESPONSE÷UNIT

ID OF RESPONSE÷UNIT NAME	NO	WORKLOAD OF UNIT	% OF MEAN	FRACTION OF DISPATCHES OUT OF DISTRICT	% OF MEAN	AVERAGE TRAVEL TIME
UNIT	1	0.323	80.9	.3043	62.4	2.717
UNIT	2	0.359	89.9	.4835	99.1	2.147
UNIT	3	0.516	129.2	.6471	132.7	1.563

PERFORMANCE MEASURES THAT ARE SPECIFIC TO EACH DISTRICT

ID OF DISTRICT NAME	NO	WORKLOAD OF DISTRICT	% OF MEAN	FRACTION OF DISPATCHES INTER-DISTRICT	% OF MEAN	AVERAGE TRAVEL TIME
DIST	1	0.438	112.5	.3895	79.9	2.772
DIST	2	0.438	112.5	.5838	119.7	2.068
DIST	3	0.292	75.0	.4795	98.3	1.223

Figure VIII-13

HYPERCUBE OUTPUT SHOWING REGION, UNIT AND DISTRICT PERFORMANCE MEASURES WHEN AVL DISPATCHING IS SPECIFIED USING THE "COMPARE" INSTRUCTION

PERFORMANCE MEASURES THAT ARE SPECIFIC TO EACH ATOM

ID # ATOM	WORKLOAD OF ATOM (#CALLS/100HR)	AVERAGE TRAVEL TIME	FREQUENCY OF PREVENTIVE PATROL PASSINGS (#/HOUR)	PROBABILITY OF ERROR
1	36.00	2.934	0.41	0.1567
2	36.00	2.450	0.00	0.0928
3	36.00	2.934	0.47	0.3063
4	36.00	1.904	0.28	0.2981
5	72.00	1.223	0.97	0.0000
6	36.00	1.904	0.30	0.3228
7	36.00	2.381	0.47	0.1823

Figure VIII-14

HYPERCUBE OUTPUT SHOWING UNIT-INDEPENDENT PERFORMANCE MEASURES SPECIFIC TO EACH REPORTING AREA WHEN AVL DISPATCHING IS COMPARED TO A USER-SPECIFIED FIXED PREFERENCE DISPATCH POLICY

PERFORMANCE MEASURES THAT ARE SPECIFIC TO EACH ATOM

ID # ATOM	FRACTION OF CALLS FOR SERVICE FROM ATOM SERVICED BY UNIT NUMBER: 1	2	3
1	0.67	0.20	0.13
2	0.64	0.12	0.24
3	0.52	0.20	0.28
4	0.18	0.38	0.43
5	0.16	0.32	0.52
6	0.21	0.36	0.43
7	0.16	0.50	0.34

Figure VIII-15

HYPERCUBE OUTPUT SHOWING FRACTION OF CALLS FOR SERVICE IN EACH REPORTING AREA SERVICED BY EACH RESPONSE UNIT WHEN AVL DISPATCHING IS SPECIFIED

AVL MEAN TRAVEL TIME FOR EACH RESPONSE+UNIT TO EACH ATOM

ATOM ID NO	ID OF RESPONSE+UNIT UNIT 1	UNIT 2	UNIT 3
1	2.05	4.54	4.56
2	2.28	3.99	2.28
3	1.25	4.54	4.56
4	4.34	1.59	1.14
5	4.56	1.71	0.00
6	4.20	1.44	1.14
7	6.84	1.08	2.28

Figure VIII-16

HYPERCUBE OUTPUT SHOWING EXACT MEAN TRAVEL TIMES FOR EACH UNIT TO EACH REPORTING AREA WHEN AVL DISPATCHING IS SPECIFIED

The table in Figure VIII-16 shows exact average travel times for each unit responding to calls in each reporting area (e.g., it takes unit 2 an average of 3.99 minutes to travel to calls in reporting area 2).

The hypercube output tables can be used to calculate additional useful performance measures. In particular, the average amount of time queued calls for service wait in the dispatcher's queue before a response unit becomes available may be determined using the formula,

$$\frac{\text{(average service time)}}{\text{(number of units)} \quad \text{X} \quad \text{(1 - average utilization factor)}}$$

This quantity is termed the average queuing delay for queued calls. Response time, the sum of travel time and queuing delay*, can then be determined using the formula

(travel time) + (queuing delay) X (saturation probability)

Response times can be computed for the region, for each district, and for each reporting area. Using the output in Figures VIII-9 and VIII-10 we see, for example, that

- o the average queuing delay for queued calls is

  (25.00) / (3 X 0.600) = 13.89 minutes
- o the average region-wide response time is

  2.209 + (13.89) X (0.141) = 2.209 + 1.958 = 4.167 minutes

*Note that this definition of response time ignores all internal processing from the time a citizen contacts the police department until a dispatcher dispatches a unit or places the call in queue because no units are available.

- the average response time to calls for service in district 1 is

  2.920 + 1.958 = 4.878 minutes

- the average response time to calls for service in reporting area 2 is

  3.163 + 1.958 = 5.121 minutes

IX. Efficient Use of the Monitor and Hypercube Programs

Procedures for minimizing the cost of hypercube analyses of existing or redesigned district plans are discussed briefly in this chapter.

1. Terminal Operations

For data processing tasks which involve large amounts of data to be input by inexperienced users and relatively little printing of output by the computer, the cost of terminal connect time can be minimized by using a terminal operating speed of 15 or 10 characters per second rather than 30. Creating or modifying region files, and creating or modifying district plan files without using the monitor are examples of such tasks. Operations involving significant amounts of terminal output, however, should be performed at the highest terminal speed possible. Also, it is much more efficient to log off the NCSS system while analyzing output or verifying the accuracy of large amounts of input data, and to log on again later for subsequent work.

2. Efficient Use of Core Storage

The amount of core storage used for on-line operations also affects the cost of terminal connect time; up to 256K bytes of core storage is charged at the hourly rate shown in Figure IV-1 -- each additional 64K increases the hourly connect charge by $1.00. This suggests that all time consuming operations (e.g., creating or modifying region files or district plan files) should be done with the core storage set to the minimum required. Thus, if the hypercube program requires more core storage than the monitor (which uses 384K), set the core storage to 384 when creating or modifying the district plan file, respond "no" when asked if performance measures are to be computed "at this time," set the core storage to the higher value required to use the hypercube program, and then use the "HYPERCUBE" command to compute performance measures on-line (core storage will be automatically reset to 256 after the hypercube program has been executed).

3. Efficient Use of the Hypercube Program

Several methods for minimizing the cost of using the hypercube program are available.

a. Overnight runs - the 60 percent reduction in the cost of hypercube runs made in a batch mode over the cost of the same runs on-line is worthwhile, particularly for users who have allowed adequate time for the analysis and redesign of their district plans, users working only part time on the analyses, or users analyzing the district plans in several different regions or time periods. Thus, several overnight runs could be made simultaneously, with the output retrieved and analyzed the following day, and district plans modified and again submitted for overnight processing.

b. Multiple workload levels - each time the hypercube program is run, a large number of preliminary calculations must be performed before the performance measures can actually be computed. When performance measures are computed for several workload levels in a single run, these preliminary calculations are made only once. Therefore, it is more efficient to make a single run specifying several workload levels than it is to make several runs specifying a single workload level each time.

c. Approximate model - as previously discussed, the results obtained using the approximation procedures available in the hypercube program are usually within a few percent of those obtained when all calculations are exact. The developers of the hypercube queuing model have estimated that for large runs (e.g., 15 districts and more than 100 reporting areas), the cost using the exact model may be 10 times as great as the cost using the approximate model (e.g., $100 compared to $10). In addition, the core storage required to use the exact model is very much greater than that required to use the approximate model, as are the associated terminal connect charges. (For example, a problem with 175 areas and 15 districts requires 1977K bytes of storage at $40 per terminal connect hour using the exact model, compared to 441K bytes at $16 per hour using the approximate model.) Therefore, the use of the approximate model is recommended unless AVL dispatching or variable response unit service times (which require the exact model) are specified.

d. Hypercube output tables - the number of tables that the user requests affects the I/O charges, even if the tables are stored and never listed at the terminal. Some output tables will not change from one run to the next unless specific changes are made in the district plan. Therefore, these tables need not be generated every time the hypercube program is used. For example, the tables showing the distribution of calls for service and the number of patrolled street miles in each reporting area do not change unless the appropriate data items in the region file are changed; the table of inter-reporting area travel times changes only when the response speed, constant of proportionality used to compute the intra-reporting area travel times, user input travel time estimates in the district plan file, or coordinate data in the region file are changed; the table of unit-to-reporting-area travel times changes only when the district configuration preventive patrol factors, or one of the items affecting inter-reporting area travel times are changed; the table showing estimated dispatch costs changes only when the dispatch policy or one of the items affecting unit-to-reporting-area travel times is changed; and the table showing the distribution of each unit's preventive patrol time is changed only when the district configuration or preventive patrol factors are changed.

e. Size of the region - when the approximate hypercube model is used, the developers of the program estimate that the cost of using the program increases approximately linearly with both the number of reporting areas in the region and the number of districts specified in the district plan (e.g., if the number of districts is doubled while the number of reporting areas remains constant, then the cost of a hypercube run approximately doubles). For this reason, it is advantageous to divide a large region into several smaller regions, or commands, and analyze each smaller region separately whenever the assumption that units are not dispatched across boundaries is reasonable. For example, suppose that a region contains 250 reporting areas and is divided into 18 districts. Suppose also that the region can be divided into two commands each with 125 reporting areas and nine districts. If the cost of using the hypercube program for one of the smaller problems is $20, then the cost of analyzing the larger problem would be approximately $80 (the cost of the smaller problem doubled by doubling the number of reporting areas, and doubled again by doubling the number of districts) compared to a total cost of $40 for analyzing both smaller problems.

X. Use of the Hypercube Software for Beat* Design and Patrol Policy Analysis

The uses of the hypercube queuing model and its supporting software fall into three general categories: the analysis of an existing district configuration, the redesign of the existing district plan, and the analysis of the effects of instituting certain policy changes relating to patrol operations. Each of these uses is discussed below. The final section in the chapter briefly summarizes beat design and patrol policy questions that are not amenable to hypercube analysis.

1. Analysis of an Existing Beat Plan

By analyzing the beat plan(s) currently in use in a police department with the hypercube programs, a commander of the patrol operations division or a department planner can determine the need for redesigning beats, and identify problem areas with the existing beat plan. The following problem areas are directly identifiable from the statistics generated as part of the hypercube output (See Chapter VIII):

- Workload imbalances among response units - by examining the workloads of the individual response units, units which are significantly over- or under-utilized relative to the region-wide average utilization can be identified.

- Inaccessibility of neighborhoods to police service - neighborhoods which do not receive rapid response to calls for service can be determined by examining the average travel times in the tables of performance measures specific to each reporting area.

- Lack of beat identity - officers consistently assigned to the same district naturally become familiar with

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*The terms "district" and "beat" are used synonomously in this chapter.

the area (i.e., addresses, one-way streets, etc.), the people in the beat, and special conditions. This familiarity can be utilized only when the unit spends most of its time in its own district. Whether or not this is actually occurring can be determined by examining the fraction of the calls handled by each unit that are in its own district, and the fraction of calls in each district that are handled by a unit from another district.

- Frequent queuing of calls for service - if a high fraction of incoming calls for service must enter the dispatcher's queue because no response units are available (i.e., if the saturation probability is high), then the need for additional response units, or the institution of some of the patrol policy alternatives discussed below, would be indicated. Note that if many calls are queued, travel times are likely to be long, and inter-district dispatches are likely to be frequent since the first unit to become available is unlikely to be the district unit.

In addition to evaluating the current beat plan under existing "average" workload condition, it is also possible to use the hypercube programs to estimate the performance of the current beat plan at predicted workload levels in future years, or at short-term, but extreme workload levels associated with a seasonal event such as a state fair. In fact, by specifying multiple workload levels, the plan can be analyzed for widely varying workloads in a single hypercube program run.

2. Redesign of a District Configuration

Having identified problem areas in the existing district configuration, the hypercube programs can be used to evaluate and compare proposed alternative configurations in terms of unit workloads, travel times, inter-district dispatches, etc. Thus, by running the hypercube programs several times changing only the district configuration and/or dispatching preferences, the plan which most nearly satisfies the department's objectives (e.g., balanced workload) can be identified.

The first step in designing a new district configuration is usually the determination of how many response units are to be on duty in the various regions of a city, and how the response units (i.e., the personnel who man them) in each region are to be allocated among the various watches. The hypercube programs could be used to do this. However, the Patrol Car Allocation Model (PCAM) was designed specifically to make this determination. While PCAM requires more extensive input data than does the hypercube program, it is preferred in this case, because a single PCAM run will determine an "optimal" allocation of units to regions and watches within user specified constraints, whereas many (more expensive) hypercube runs would be required. PCAM, however, cannot be used to design the beats to be patrolled by each unit, or to compare alternative beat configurations. For this, the hypercube programs are most suitable.

In some cases, the alternative configurations to be considered will have been identified by field commanders before any hypercube analyses have been made. This is the least complex way to use the hypercube programs for beat design. By running the program once for each alternative, the results can be used comparatively to rank the plans and select the most acceptable. Then, a relatively small number of runs are required; and, the number of runs and the amount of effort involved will be known in advance.

In other cases, the designer will have a set of contraints within which he must work, and a set of objectives in mind, but no preconceived idea of the exact district plans that he wants to consider. Rather, he seeks the "best" plan possible. This form of beat design using the hypercube programs is more complex since the model is strictly descriptive, rather than prescriptive. That is, it can compute performance measures for plans provided by the user, but cannot suggest changes for improving the plan. As a result, the user must develop a district configuration, submit it to the hypercube program, and retrieve and analyze the results. The procedure may be repeated many times until the user finds a plan acceptable to department administrators.

Modifications to the district configuration require a thorough knowledge of how to interpret hypercube output, certain underlying principles of beat design, how specified changes in the district configuration will affect performance, and how to modify the configuration to achieve a desired result.

a. Principles of beat design

The following principles of beat design may be useful when considering alternative beat plans: [1, 16]

- The shape of a beat is not particularly important so long as it is compact.
- If the x and y directional travel speeds are different, the long dimension of the beat should be in the direction of the higher speed.
- If beats do not overlap, and each car's workload is not too great, the fraction of dispatches that are across beat boundaries is at least as high as the fraction of time the average unit is unavailable. If car workloads are high, the fraction of intra-beat dispatches is approximately one divided by the number of cars in the region. Inter-beat dispatching is 1 - intra-beat dispatching.

- A patrol unit's workload is not equal to the workload generated by calls originating in its beat.

- The "burden of central location" suggests that cars assigned to peripheral beats (those on the boundary of the region) will have lower workloads than centrally located cars, if the call volumes in all beats are equal, due to the lower likelihood of cross-beat-dispatching for peripheral cars.

- Average travel times increase with workload and with the size of beats.

- Average travel time is relatively insensitive to moderately large barriers.

- If district boundaries coincide with travel barriers, the barriers have no effect on average intra-district travel times.

- Incremental changes in the number of units have small effects on average intra-district travel times.

- If the call for service rate doubles, the number of response units need not be doubled to keep the average queue delay at the same level.

b. Effect of transferring reporting areas between adjacent beats[2]

When reporting area X is transferred from beat A to an adjacent beat B, the following effects should be anticipated:

- Patrol unit A's workload will decrease because its area of responsibility has been reduced; conversely unit B's workload will increase.

- The change in unit workloads will be partially offset, however, because unit A will be available more often for cross-beat dispatches, and because more cross-beat dispatches will be required to provide rapid response to calls for service originating in beat B. (Unit B will not be available as often to answer calls originating within its own beat.)

- The average travel time for response to calls originating in beat A will be lowered if the average travel time to calls in reporting area X was greater than the overall travel time average for all calls in beat A.

- o The average travel time for response to calls originating in beat A will also be lowered because the reduced number of calls originating in that beat will decrease the number of cross-beat dispatches of cars from other beats into beat A.
- o The average travel time for response to calls originating in reporting area X will decrease if X is closer to the center* of beat B than to the center of beat A.
- o The average travel time for response to calls originating in reporting areas on the side of beat A opposite from reporting area X will decrease because they will be closer to beat A's center after area X is moved to beat B.

c. Selecting reporting areas to be transferred from one beat to an adjacent beat

The following techniques can be used to select reporting areas in beat A for transfer to beat B if it is desired to produce the following types of changes in the specified performance measures:

- o Reducing workload imbalance - if unit A has the greatest workload, determine the adjacent beat B whose unit has the lowest workload, and transfer the reporting area X in beat A that is closest to the center of beat B. Alternatively, if unit B has the least workload, transfer into beat B the reporting area X, which is closest to beat B's center, and which is presently located in the adjacent beat with the greatest workload.
- o Reducing travel time imbalance among beats - if beat A has the highest average travel time, determine the adjacent beat B with the lowest average travel time, and transfer from A to B the reporting area X that is farthest from A's center.
- o Reducing travel time imbalance among reporting areas - if reporting area X in beat A has the highest average travel time and is closer to beat B's center than to

---

*Unless otherwise specified, "center" will refer to the geographic center of a beat as weighted by the relative distribution of preventive patrol assigned to each of the reporting areas in the beat.

beat A's, then X should be transferred from A to B. Alternatively, the reporting area Y in beat A which is farthest from reporting area X should be transferred to the adjacent beat with the closest center.

3. Analysis of Policy Changes in Patrol Operations

In addition to changes in the assignment of patrol areas to individual units, proposed changes in department policies governing patrol operation can also be analyzed using the hypercube programs. ("Any changes that could possibly be shown on a dispatcher's map are suitable for analysis using the hypercube model."[17]) Thus, the potential effect of innovative policies or expensive technological tools (e.g., automatic vehicle locators) can be studied before the policies are actually changed or the tools are actually purchased and implemented.

The following changes can be analyzed by making straightforward modifications to the input data in the district plan file:

a. Alternative preventive patrol strategies - by modifying the preventive patrol factors associated with each reporting area in each unit's beat, a variety of patrol strategies can be represented (e.g., patrol proportional to reporting area workload, uniform patrol in all reporting areas of a beat, or any other distribution of patrol time over the various reporting areas). The analysis, of course, is limited to determining the effects on the calculated performance measures (workloads, hourly patrol passings, etc.). That is, the various strategies are not quantified in terms of their value in intercepting crimes in progress, facilitating on-scene arrests, or deterring street crime.

b. Team policing - team policing can be represented by assigning the same beat to several units (the number of units is determined by the size of the teams) with the beats assigned to the teams typically larger than conventional beats. Design of each team's area of responsibility is performed using the same procedures discussed in the preceding section. Because of the way the hypercube program defines inter-district dispatches when beats overlap (i.e., a dispatch is treated as inter-district only if the reporting area of the call is not in the beat of the dispatched unit) the fraction of dispatches that are inter-district should be less when team policing is analyzed. Note that other hypercube output statistics may require special interpretations when several beats overlap. Also, special attention must be paid to specifying dispatch preferences among the units whose beats overlap, since otherwise the hypercube program will assume that the units appearing first in the district plan file are dispatched first if available. The output will then indicate an unrealistically high workload for those units.

c. Vehicle location systems - using the AVL dispatching policy provided in the hypercube program, the type of dispatch operation in which the dispatcher always knows exact unit locations, and always dispatches the closest available units to a call for service, can be represented. Therefore, the effects (e.g., on travel times) of replacing manual, fixed preference dispatching with automatic vehicle locator systems can be analyzed to determine whether the potential benefits justify the cost of such systems. By examining dispatch error probabilities, it is possible to determine the fraction of calls for which the dispatcher's perception of which car is closest, is incorrect using the current dispatch policy (i.e., SCM, ESCM, MCM, or EMCM). This fraction will not necessarily be the same as the fraction of calls to which the closest car is not dispatched if the current dispatch policy includes special procedures in certain situations (i.e., first dispatch preferences for particular units in selected reporting areas). Typical results of analyzing AVL dispatching might be as follows: 16

- At most, a 10 to 20 percent reduction in travel times can be expected when SCM-type dispatching is replaced by AVL dispatching.
- Average travel time reductions as a result of AVL dispatching are less at heavier workloads.
- Dispatch error is higher when the average utilization is low.
- Vehicle location information is more valuable in large regions with more units because of the larger number of dispatch alternatives.

d. Alternative dispatch policies - in addition to analyzing the benefits derived from obtaining more exact information on the location of response units, the hypercube programs can be used to analyze the effects of the following alternative dispatch policies:

- Dispatch of the "closest" available unit versus dispatch of an available beat car, regardless of its location.

- Use of special (non-response) units to handle calls for service arriving when no units are available versus queuing the calls until a response unit becomes available (i.e., zero versus infinite capacity queue).

- Stacking of calls at the beat level when no beat car is available (i.e., eliminate all inter-beat dispatches). This requires a separate hypercube analysis of each beat or team area covered by several units.

- Use of region-wide dispatching in which command boundaries are eliminated and all units are assigned patrol responsibility throughout the region (although patrol factors associated with individual units may differ).

e. Screening of calls for service prior to dispatch - when faced with an increasing number of calls for service and an inability to increase manpower, some departments may consider adopting a policy of either not responding to some types of calls for service, or assigning these calls to non-response units (e.g., assigning cadets to take burglary reports). Such policies are represented by reducing both average call rate and reporting area workloads to reflect the overall fraction of calls being screened and the distribution of screened calls over the reporting areas.

f. One-man versus two-man cars - the effects of having two men in each unit rather than one are that more than one unit will be dispatched less frequently, and there will probably be fewer units on patrol unless department manpower is greatly increased. Fewer units on-duty require the design of a new beat plan with fewer districts as described above. Multiple car dispatching can be represented only by inflating the call for service rate. Therefore, if two-man units are to be utilized, the call rate must be readjusted to reflect the projected fraction of calls which would then require multiple units. An estimate of the fraction of calls requiring two two-man units might be the fraction of calls previously requiring three or four one-man units. Once this estimate and the estimated service time for the second unit dispatched have been made, the monitor program will calculate the adjusted call rate if the "ADJUST" subcommand is used, or the adjusted call rate can be computed manually as described below.

The following features of patrol operations are not directly represented in the hypercube model. If they are important features of a department's current or proposed operation, then the adjustments indicated will need to be made:

g. <u>Non-random arrival of calls for service</u> - in some departments, calls for service may not occur randomly throughout the watch being analyzed. For example, calls for service may be relatively high at the beginning of the 3:00 p.m. to 11:00 p.m. watch in a region with many businesses, but the calls may decrease later in the watch as the population of the area decreases when the businesses close. Similarly, non-CFS workload may be non-random (e.g., some units may be unavailable during certain periods every day when assigned duties in school zones). When such non-random workload occurs, separate analyses may need to be made during the periods when the call rates are significantly different, or during periods when the number of units is effectively reduced by the non-random, non-CFS work.

h. <u>Multiple car dispatching</u> - In some departments dispatchers frequently assign two or more cars to respond to incoming calls. Because the hypercube model assumes that only one car is dispatched to each incident, the model will underestimate beat car workloads if the data base does not include information on the service time required of dispatched units other than the first car sent to a call. Consequently, if input call data refers only to the first car sent, and if multiple car dispatching is not infrequent, the volume of incoming calls should be increased sufficiently to account for the work of the second and subsequent cars. The monitor program will calculate an adjusted call rate if the "ADJUST" subcommand is used, or it can be determined by the user by calculating the following adjustment factor:

$$\begin{pmatrix}\text{adjustment}\\ \text{factor}\end{pmatrix} = \left[\begin{pmatrix}\text{average service}\\ \text{time for first}\\ \text{dispatched unit}\end{pmatrix} + \begin{pmatrix}\text{fraction of}\\ \text{calls that}\\ \text{require 2 or}\\ \text{more units}\end{pmatrix} \times \begin{pmatrix}\text{average service}\\ \text{time for second}\\ \text{dispatched unit}\end{pmatrix} + \begin{pmatrix}\text{fraction of}\\ \text{calls that}\\ \text{require 3 or}\\ \text{more units}\end{pmatrix} \times \begin{pmatrix}\text{average service time}\\ \text{for third dispatched}\\ \text{unit}\end{pmatrix} + \ldots\right] \Big/ \begin{pmatrix}\text{average service}\\ \text{time}\end{pmatrix}$$

The adjusted call rate is

$$\begin{pmatrix}\text{adjusted}\\ \text{call rate}\end{pmatrix} = \begin{pmatrix}\text{adjustment}\\ \text{factor}\end{pmatrix} \times \begin{pmatrix}\text{unadjusted}\\ \text{call rate}\end{pmatrix}$$

and, the adjusted incremental call rate is

$$\begin{pmatrix}\text{adjusted}\\ \text{increment}\end{pmatrix} = \begin{pmatrix}\text{adjustment}\\ \text{factor}\end{pmatrix} \times \begin{pmatrix}\text{unadjusted}\\ \text{increment}\end{pmatrix}$$

i. Non-call-for-service work - non-CFS workload can be represented only by adjusting the call for service rate. One way to do this would be to treat each non-CFS incident (i.e., officer-initiated "calls," meals, etc.) as a call for service. This could produce erroneous results, however, if past data are used to estimate the number of non-CFS incidents and, for example, the number of units is changed because of difficulties in estimating the effect this change will have on the non-CFS work. Similarly, ignoring non-CFS workload completely will produce unrealistic estimates of unit workloads, saturation probability, etc. Thus, the necessary adjustment to the call rate should depend on the number of units as follows:

$$\begin{pmatrix}\text{adjusted}\\ \text{arrival rate}\end{pmatrix} = \begin{pmatrix}\text{call}\\ \text{rate}\end{pmatrix} + \left[\begin{pmatrix}\text{number}\\ \text{of}\\ \text{units}\end{pmatrix} \times \begin{pmatrix}\text{average minutes}\\ \text{per hour each unit}\\ \text{spends on non-CFS}\end{pmatrix}\right] / \begin{pmatrix}\text{specified}\\ \text{service}\\ \text{time}\end{pmatrix}$$

Note that the incremental call rate is not adjusted when multiple workload levels are specified.

j. Cross-command dispatching - when the number of cross-command dispatches is relatively small, they can be ignored in the hypercube analysis. If it is necessary to account for the cross-command dispatches, the commands may have to be combined and the larger area analyzed. Alternatively, it may be possible to approximate cross-command dispatching by adding "artificial" reporting areas at the boundaries of the region. The workload of such a reporting area would depend on the number of dispatches of units into the command that reporting area represents. Units dispatched from other commands into the region being analyzed would be represented as backup units handling all calls arriving when all response units in the region are busy. Note that when this technique is used, travel time statistics may not be accurate and should therefore be used only qualitatively.

k. Beat-dependent service times - when the types of calls occuring in different beats vary considerable, the average service times for calls may also vary significantly from beat to beat. The hypercube model allows unit-dependent service times but makes no provision for beat-dependent service times. If variable unit service times are used to approximate the variable beat service times, they apply to all calls serviced by the units. Consequently, the approximation is less reliable when the fraction of dispatches that are inter-district is high. Since variable service times can be specified only when the exact hypercube model is used, this approximation cannot be used in regions with a large number of units (i.e., at most, 15 units can be specified when the exact model is used). Alternatively, call arrival rates in each beat should be adjusted so that the number of service hours per watch is correct. This adjustment is made by scaling the workload of the reporting areas in the region file. For example, if the region-wide average service time is 30 minutes, but the service time in beat A averages only 15 minutes, the call volumes of each reporting area in beat A should be halved.

4. Patrol and Dispatch Policies Not Amenable to Hypercube Analysis

The current versions of the hypercube programs make no provision for the following features of patrol and dispatch policies:

- Priority-based dispatch policies - the hypercube model treats all calls for service, including those in the dispatcher's queue, as equal in priority. Priority-based dispatch policies cannot be represented.

- Preemptive dispatch assignments - the reassignment (e.g., to a higher priority call) of units servicing or enroute to a previous call is not allowed.

- Selective stacking of calls - hypercube dispatch policies cannot model the selective queuing of low priority calls when the beat unit is unavailable.

- Servicing of calls in queue in any manner other than first-come first-served - the hypercube model permits calls in queue to be serviced on a first-come, first-served basis only. Priority servicing of calls in queue, or the dispatching of units to the call in queue that is closest to their current locations cannot be represented.

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APPENDIX A

GLOSSARIES OF DATA PROCESSING

AND POLICE TERMS

Table A-1

GLOSSARY OF DATA PROCESSING TERMS[3,7,14,15]

Auxiliary Storage: Data storage other than core storage.

Batch Processing: A technique that permits multiple jobs to be collected for presentation to the system, which automatically recognizes and processes each job, one after the other.

Benchmark: To ascertain comparative performance of systems by use of a set of test programs designed specifically to exercise vital system software and hardware features.

Carriage Return: The signal that indicates to the system the termination of a line of input from the terminal.

Character: One symbol of a set of elementary symbols such as those corresponding to the keys on a typewriter. The symbols usually include the decimal digits 0 through 9,the letters A through Z, punctuation marks, operation symbols, and any other single symbols which a computer may read, store, or write.

Character-Delete Symbol: A character appearing on the terminal keyboard which, when pressed 'n' times, will delete the preceding 'n' characters and itself from the input line.

Column: Generally a character or digit location in a positional-information format, most often one in which characters appear in rows.

Computer: A device capable of accepting information, applying prescribed processes to information, and supplying the results of these processes. It usually consists of input and output devices, arithmetic, storage, communications units and a control unit.

Connect Time: The quantity of time that passes while the user of a remote terminal is connected to a time-shared system. Connect time is usually measured by the duration between log-on and log-off.

Conversational Processing: An important time-sharing operation in which the user is said to be communicating with the system in a conversational manner when each statement he enters through the terminal is processed immediately. The system then sends a reply to the terminal.

Core Storage: The fundamental and most important storage of the central processing unit.

CPU (Central Processing Unit): The unit of a system that contains the circuits that control and perform the execution of computer instructions.

File: A collection of related records treated as a unit.

Flowchart: A chart to represent, for a problem, the flow of data, procedures, etc; or graphical representation of a sequence of operations by using symbols to represent the operations.

Full-Duplex: In communications, pertaining to a simultaneous two-way and independent transmission in both directions.

Half-Duplex: Pertaining to an alternate, one-way-at-a-time, independent transmission.

Hard Copy: A printed copy of machine output in readable form.

Input: The data to be processed; or the process of transferring data into a storage medium internal to a computer or computer system.

Interactive Mode: A procedure for communication between a terminal and the computer in which each entry from the terminal elicits a response from the computer and vice versa.

Kilo(K): In reference to memory devices, kilo means 1024; e.g., 4K byte memory is actually 4096 bytes.

Line-Delete Symbol: A character input from the terminal that deletes all preceding characters in the input line and itself.

Network: A series of points interconnected by communications channels.

Noise: An undesired disturbance in a communication system which can generate errors or spurious messages.

Null Line: An input line consisting of a carriage return issued as the first and only information.

Off-Line: Pertaining to equipment or devices not under direct control of the central processing unit. May also be used to describe terminal equipment not connected to a transmission line.

On-Line: Any operation performed at a terminal which is actively connected to the computer.

On-Line Data Processing: The input (and output) of data (and reports) in a direct fashion to the computer over local or remote communications lines.

Output: Data that has been processed; or the process of transferring data from an internal storage to an external storage device.

Password: The unique set of digits or characters assigned to a user as part of his identification number in communicating with the computer.

Program: A set of instructions or steps that tells the computer exactly how to solve a problem.

Program Runs: A run refers to the actual execution or operation of a program.

Right Justified: In most cases data is considered right justified when the right-hand digit or character occupies the right-hand position of the space (field) allotted for that data.

Software: Refers to the procedural specifications required to operate computers as embodied in program code (as opposed to the computing machinery or hardware).

Storage: A general term for any device capable of retaining information.

System: Refers to a set of hardware, programs (software), procedures, personnel, etc. required to perform a given task or set of tasks.

Terminal: An input/output device designed to receive or send source data in an environment associated with the job to be performed and capable of transmitting entries to and obtaining output from the system of which it is a part.

Terminal Session: The period between a user's completed log-on until he logs off.

Time-Sharing: A method of operation in which a computer facility is shared by several users for different purposes at (apparently) the same time. Although the computer actually services each user in sequence, the high speed of the computer makes it appear that the users are all handled simultaneously.

User: Anyone who requires the services of a computing system.

Table A-2

GLOSSARY OF POLICE TERMS[6]

Beat: Same as district.

Beat Identity: Same as district identity.

Call for service: A communication to the police originating from a citizen, an alarm system, a police officer, or other detector, reporting an incident that requires on-scene police assistance.

Dispatch assignment: A directive by the dispatcher to a patrol unit assigning the unit to respond to the scene of a reported incident or call for service.

Dispatcher: An individual who has responsibility for assigning available radio-dispatchable patrol units to reported incidents.

District: An area in which one patrol unit has (usually exclusive) preventive patrol responsibility. When districts overlap, such responsibility is no longer exclusive, but each car's district is the area in which it is expected to perform preventive patrol.

District identity: A term applied to an officer's personal commitment to maintain public order and provide effective police service within his home district.

Effective travel speed: That speed which, if constantly maintained over the path of a response journey, would result in the same travel time as that actually experienced by the responding patrol unit.

Flying: A term applied to a patrol unit responding frequently to calls outside its assigned district (home district).

Hazard formula: A summation of crime statistics, geographical statistics, and other factors thought to be important in determining the need for patrol units in a region. Each factor is multiplied by a weight indicating its subjective importance.

Home district: The district in which a patrol unit is assigned to perform preventive patrol.

Inter-district (or cross-district) assignment: A dispatch assignment to a district other than the unit's home district.

Overlapping districts: Districts that share at least some common regions, such as reporting areas.

Patrol allocation: The entire process of determining the total required number of patrol units, their spatial and temporal assignments, and rules governing their operation.

Patrol status: The condition of a patrol unit, particularly pertaining to dispatch availability. In some police departments the dispatch status of a patrol unit is restricted to one of two possibilities: available or unavailable; in others, finer distinctions are made, including such possibilities as meal break, auto maintenance, patrol-initiated action, stationhouse, or type of incident currently being serviced.

Patrol unit: A patrol car, scooter, or wagon and its assigned police officer(s); or a radio-dispatchable foot patrolman.

Preventive patrol: An activity undertaken by a patrol unit, in which the unit tours an area, with the officer(s) checking for crime hazards (for example, open doors and windows) and attempting to intercept any crimes while in progress.

Reporting area: A subarea within a district sometimes no more than a few city blocks in size, that is used as the smallest geographical unit for aggregating statistics on the spatial distributions of calls for service and preventive patrol coverage.

Region: A group of districts administered as an autonomous field operations territory.

Sector: A term used synonymously with district in some police departments.

Service time: The total "off the air" or "out of service" time per call for service for a patrol unit. Includes travel time, on-scene time and possibly related off-scene time.

Travel time: The time required for the dispatched patrol unit to travel to the scene of the reported incident from its location when the assignment was received.

Utilization factor: The fraction of time, on the average, a patrol unit would be busy handling calls for service if all incoming calls were queued until a car became free to handle them. When hypercube analyses are run assuming a zero capacity queue, the average workload will be less than the average utilization factor.

Workload: The fraction of time, on the average, a patrol unit is busy handling calls for service. (See also "utilization".) In hypercube analyses, the workload generated by a district is equal to the fraction of time a single car would be busy handling calls originating in the district if the district were an autonomous region.

APPENDIX B

<u>SAMPLE TERMINAL SESSION ILLUSTRATING</u>

<u>ANALYSIS OF A DISTRICT PLAN</u>

APPENDIX B

SAMPLE TERMINAL SESSION ILLUSTRATING ANALYSIS OF A DISTRICT PLAN

The following annotated printout was produced using the interactive hypercube programs to analyze a district plan for a region described by the region file LAWCITY. The comments added are intended to clarify computer or user statements. Input to the monitor was based on the following information about patrol operations (See also Figure III-1):

(1) The terminology used to describe field operations in the department is (in terms of hypercube's terminology):

district = zone
unit = car
atom = reporting bloc
calls for service = incidents
travel time = travel time

(2) Service time for incidents (including travel time) averages 22 minutes per incident.

(3) Incidents for the entire region arrive at an average of six per hour.

(4) When responding to incident patrol cars travel at an average of 20 mph, but while engaged in preventive patrol they travel at an average of 10 mph.

(5) Dispatch policy is approximately SCM. When the car assigned to a zone is available it is first choice for incidents arriving in that zone. If no zone cars are available when an incident arrives, dispatchers are instructed to assign the incident immediately to a backup unit (e.g., a supervisor, detective, or canine unit). It is assumed that enough backup units are available to avoid any queuing of incidents at the dispatching center. In general, the dispatchers assign incidents to the closest car (unless the assigned zone car is free, but is not the closest available car).

(6) The travel times associated with cars being dispatched to an incident located in the same reporting bloc as the car was when it received the assignment should be approximated using the command CORTM = 0.90.

(7) When on preventive patrol the time spent by a zone car in any of the reporting blocs in its beat is proportional to the workload in the reporting bloc.

(8) Three zones, covered by one zone car, are to be used. Zone 1 contains reporting blocs 121, 131, 141, 151, and 161. Zone 2 contains reporting blocs 71, 81, 91, 101, and 111. Zone 3 contains reporting blocs 11, 21, 31, 41, 51, and 61.

(9) Use the approximate hypercube model for the analysis. Display all available output tables.

```
10.56.47 >SET CORE 384  <----  [Core must be set to at least 384
CSS.300 06/15/76                (thousand) to create or change a
                                district plan.]

10.57.14 >MONITNEW  <----  [Routine for creation of a new district plan.]
ENTER NAME OF REGION FILE (I.E., THE NAME OF THE FILE THAT
CONTAINS GEOGRAPHIC AND CALL VOLUME DATA FOR EACH REPORTING
AREA IN THE REGION OF INTEREST)>LAWCITY
ENTER NAME TO BE GIVEN TO THE NEW DISTRICT PLAN BEING CREATED>DISTPLAN
EXECUTION:
```

[This name serves as the name of the computer file which will contain the description of the district plan.]

```
NSF/RANN INTERACTIVE HYPERCUBE SYSTEM

MONITOR HERE.  WHEN IN DOUBT, TYPE '?' .

THE INTERACTIVE MONITOR USES SPECIFIC TERMS TO REFER TO
RESPONSE UNITS, CALLS FOR SERVICE, ETC. WHICH MAY BE
DIFFERENT FROM THOSE YOU ARE ACCUSTOMED TO.  WHILE THIS
TERMINOLOGY CANNOT BE MODIFIED WITHIN THE MONITOR ITSELF,
IT IS POSSIBLE TO PROVIDE YOUR OWN TERMS TO BE USED IN THE
FINAL HYPERCUBE OUTPUT BY USING THE "GLOSSARY" COMMAND
AFTER FIRST CREATING YOUR DISTRICT PLAN.  DO YOU WANT AN
EXPLANATION OF THE TERMINOLOGY BEING USED BY THE MONITOR?:
>YES


REPORTING AREA -- "REPORTING AREA" REFERS TO THE SMALLEST
   GEOGRAPHICAL UNIT (TYPICALLY NO MORE THAN A FEW CITY
   BLOCKS IN SIZE) FOR AGGREGATING STATISTICS ON THE
   SPATIAL DISTRIBUTIONS OF CALLS FOR SERVICE AND PRE-
   VENTIVE PATROL COVERAGE (REFERRED TO AS 'ATOM' IN THE
   "GLOSSARY" COMMAND).

DISTRICT -- "DISTRICT" REFERS TO AN AREA IN WHICH ONE PATROL
   UNIT HAS PREVENTIVE PATROL RESPONSIBILITY.  SYNONYMOUS
   TERMS USED IN SOME JURISDICTIONS INCLUDE "SECTOR" AND
   "BEAT" (REFERRED TO AS 'R_DIST' AND 'NM_DIST'
   IN THE "GLOSSARY" COMMAND).

REGION -- "REGION" REFERS TO AN AREA COMPRISED OF ONE OR
   MORE DISTRICTS THAT IS ADMINISTRARILY DISTINCT.
   ALTERNATIVE TERMS INCLUDE "COMMAND" AND "PRECINCT."

UNIT -- "UNIT" REFERS TO A PATROL CAR AND ITS ASSIGNED
   POLICE OFFICER(S), OR TO A RADIO-DISPATCHABLE FOOT
   PATROLMAN (REFERRED TO AS 'R_UNIT' AND 'NM_UNIT'
   IN THE "GLOSSARY" COMMAND).

CALL FOR SERVICE -- "CALL FOR SERVICE" REFERS TO A COMMUNI-
   CATION TO POLICE REPORTING AN INCIDENT THAT REQUIRES
   ON-SCENE POLICE ASSISTANCE (REFERRED TO AS 'CFS' IN
   THE "GLOSSARY" COMMAND).
```

TRAVEL TIME -- "TRAVEL TIME" REFERS TO THE TIME REQUIRED FOR THE DISPATCHED UNIT TO TRAVEL TO THE SCENE OF THE REPORTED INCIDENT FROM ITS LOCATION WHEN THE ASSIGNMENT WAS RECEIVED (REFERRED TO AS 'T_COST' IN THE "GLOSSARY" COMMAND).

ENTER COMMAND:
>?

Liberal use of the "?" feature is made during this run to demonstrate the program's tutorial capabilities.

YOU ARE NOW AT COMMAND LEVEL.
THE COMMAND 'LISTCMDS' LISTS ALL AVAILABLE BASIC COMMANDS.
THE COMMAND 'LISTADVCMDS' LISTS ADVANCED COMMANDS.
THE MOST FREQUENTLY USED COMMANDS ARE THE FOLLOWING:

CREATE -- LEADS THE USER THROUGH CREATION OF A NEW DISTRICT PLAN FILE.
MODIFY -- LEADS THE USER THROUGH MODIFICATION OF AN ALREADY

At some points, seemingly random to the terminal user, the computer skips a number of lines before carrying on with a printout. This has no significance.

EXISTING DISTRICT PLAN FILE.
CONFIG -- LEADS US'.' THROUGH MODIFICATION OF DISTRICT CONFIGURATION
SUMMARY -- TYPES OUT SUMMARY OF CURRENT PLAN INCLUDING ANY MODIFICATIONS MADE.
SAVE -- SAVES THE NEW DISTRICT PLAN FILE AND TERMINATES THE MONITOR PROGRAM.
EXIT -- TERMINATES THE MONITOR PROGRAM WITHOUT SAVING THE NEW DISTRICT PLAN FILE.

ENTER COMMAND:
>LISTCMDS

Lists all other basic commands.

THE FOLLOWING ADDITIONAL COMMANDS ARE AVAILABLE:

INSPECT -- LIST ANY REPORTING AREAS THAT ARE NOT IN ANY DISTRICT OR THAT ARE IN MORE THAN ONE DISTRICT.

PRINTDIST -- PRINT THE CURRENT DISTRICT CONFIGURATION.

WORKLOAD -- MODIFY THE NUMBER OF WORKLOADS FOR WHICH PERFORMANCE MEASURES ARE TO BE COMPUTED, THE BASE ARRIVAL RATE OF CALLS FOR SERVICE, OR THE INCREMENTAL ARRIVAL RATE OF CALLS FOR SERVICE.
(SEE USER'S MANUAL, P. 23, FOR FURTHER EXPLANATION OF WORKLOADS.)

TITLE -- MODIFY THE TITLE OF THE PLAN.

POLICY -- MODIFY THE DISPATCHING POLICY: SCM, MCM, ESCM, EMCM, OR AVL. ← Further explanation of policies appears later.

FRST -- DECIDE WHETHER THE DISTRICT CAR IS ALWAYS TO BE DISPATCHED FIRST, WHEN IT IS AVAILABLE, TO CALLS IN ITS DISTRICT.

QUEUE -- DECIDE WHETHER A QUEUE IS ALLOWED TO BUILD UP IF MORE CALLS FOR SERVICE ARRIVE THAN THERE ARE UNITS AVAILABLE.

SPEED -- MODIFY THE RESPONSE SPEED OF PATROL UNITS.

ENTER COMMAND:
>LISTADVCMDS ← Lists advanced commands.

IN ADDITION TO THE "BASIC" COMMANDS, CREATE, MODIFY, CONFIG, SUMMARY, SAVE, EXIT, INSPECT, PRINTDIST, WORKLOAD, TITLE, POLICY, FRST, QUEUE, AND SPEED, THERE ARE MONITOR COMMANDS WHICH FACILITATE USE OF ADVANCED MONITOR FEATURES (DESCRIBED IN USER'S MANUAL). THE FOLLOWING ADVANCED MONITOR COMMANDS ARE AVAILABLE:

ADJUST -- ADJUSTS THE CALL RATE TO ACCOUNT FOR MULTIPLE CAR DISPATCHES AND/OR NON-CALL-FOR-SERVICE WORK.

BACK -- ASSIGNS LAST DISPATCH PREFERENCE TO A PARTICULAR UNIT IN SELECTED REPORTING AREAS.

Note the "underscore" symbol, a required character here.

COMPARE -- SPECIFIES THAT PERFORMANCE MEASURES ARE TO BE COMPUTED ASSUMING THE AVL DISPATCH POLICY, AND THAT DISPATCH ERROR PROBABILITIES ASSUMING THE DISPATCH POLICY INPUT BY THE USER (I.E., SCM, MCM, ESCM, EMCM) ARE TO BE COMPUTED. •

CORTM -- SPECIFIES CONSTANT OF PROPORTIONALITY TO BE USED IN COMPUTING INTRA-REPORTING AREA TRAVEL TIMES.

D_SCALE -- SPECIFIES CONSTANT BY WHICH X,Y COORDINATES IN REGION FILE ARE TO BE MULTIPLIED TO CONVERT THEM TO MILES.

FRONT -- ASSIGNS FIRST DISPATCH PREFERENCE TO A PARTICULAR UNIT IN SELECTED REPORTING AREAS.

GLOSSARY -- SPECIFIES TERMS TO BE USED IN HYPERCUBE OUTPUT TO REFER TO REPORTING AREAS, DISTRICTS, RESPONSE UNITS, CALLS FOR SERVICE, AND TRAVEL TIME.

MIDDLE -- ASSIGNS A SPECIFIC COST OF DISPATCHING A PARTICULAR UNIT TO SELECTED REPORTING AREAS.

NO_PRNT -- SPECIFIES THAT ONLY HYPERCUBE OUTPUT SHOWING REGION, UNIT, AND DISTRICT SPECIFIC PERFORMANCE MEASURES IS TO BE PRINTED.

PATROL -- SPECIFIES THE EFFECTIVE PATROL SPEED OF RESPONSE UNITS AND REQUESTS THAT THE FREQUENCIES OF PREVENTIVE PATROL PASSINGS BE CALCULATED.

PRNT_ALL -- SPECIFIES THAT ALL HYPERCUBE OUTPUT, EXCEPT INTER-REPORTING AREA TRAVEL TIMES, IS TO BE PRINTED.

PRNT_ATOM -- SPECIFIES THAT A TABLE IS TO BE PRINTED SHOWING ATOM SPECIFIC PERFORMANCE MEASURES. *

PRNT_CFS -- SPECIFIES THAT A TABLE IS TO BE PRINTED SHOWING THE DISTRIBUTION OF CALLS FOR SERVICE BY REPORTING AREA. *

PRNT_COST -- SPECIFIES THAT A TABLE IS TO BE PRINTED SHOWING THE ESTIMATED COST OF DISPATCHING EACH RESPONSE UNIT TO EACH REPORTING AREA. *

PRNT_PATROL -- SPECIFIES THAT A TABLE IS TO BE PRINTED SHOWING THE NUMBER OF PATROLABLE STREET MILES IN EACH REPORTING AREA.

PRNT_SP_ALC -- SPECIFIES THAT A TABLE IS TO BE PRINTED SHOWING THE SPATIAL ALLOCATION AMONG REPORTING AREAS OF RESPONSE UNITS WHEN AVAILABLE. *

PRNT_TR -- SPECIFIES THAT A TABLE IS TO BE PRINTED SHOWING INTER-REPORTING AREA TRAVEL TIMES. *

PRNT_TT -- SPECIFIES THAT A TABLE IS TO BE PRINTED SHOWING THE MEAN TRAVEL TIMES OF EACH RESPONSE UNIT TO EACH REPORTING AREA. *

PRNT_VST -- SPECIFIES THAT A TABLE IS TO BE PRINTED SHOWING THE VARIABLE SERVICE TIME ASSOCIATED WITH EACH RESPONSE UNIT. *

STATISTICS -- SPECIFIES WHETHER HYPERCUBE STATISTICS ARE TO BE CALCULATED USING THE EXACT MODEL, THE APPROXIMATE MODEL, OR BOTH.

STORE -- SPECIFIES THAT THE DISTRICT PLAN FILE IS TO BE SAVED WITHOUT TERMINATING THE MONITOR.

TXOV -- SELECTIVELY OVERRIDES CALCULATION OF INTER-REPORTING AREA TRAVEL TIMES USING THE MANHATTAN METRIC BY DIRECTLY SPECIFYING THE TRAVEL TIME BETWEEN PAIRS OF REPORTING AREAS.

VST -- SPECIFIES INDIVIDUAL AVERAGE SERVICE TIMES FOR EACH RESPONSE UNIT.

* THESE COMMANDS ARE ALSO USED TO SPECIFY THAT TABLES ARE NOT TO BE PRINTED. FOR EXAMPLE, THE USE OF THE "PRNT_COST" COMMAND AT A TIME WHEN A DISTRICT PLAN DOES NOT CALL FOR THE PRINTING OF A TABLE OF DISPATCH COSTS WILL CAUSE SUCH A TABLE TO BE PRINTED. ON THE OTHER HAND, IF THE DISTRICT PLAN SPECIFIES THAT THE TABLE OF DISPATCH COSTS IS TO BE PRINTED, THE USE OF THE "PRNT_COST" COMMAND WILL SPECIFY THAT IT IS NOT TO BE PRINTED. NOTE THAT UNTIL THE USER INDICATES OTHERWISE, NONE OF THE TABLES WILL BE PRINTED.

Note that this footnoote does not apply to the PRNT_ALL command.

```
ENTER COMMAND:
>CREATE
```

Begin specification of district plan.

```
ENTER TITLE OF DISTRICT PLAN:
>?
THE TITLE OF THE PLAN CAN BE ANYTHING YOU CHOOSE AS LONG AS
   IT IS ONLY ONE LINE LONG AND HAS A LENGTH OF 50
   CHARACTERS OR LESS.
(NOTE: THIS TITLE HAS NOTHING TO DO WITH THE NAME
   OF THE DISTRICT PLAN FILE.)

ENTER TITLE OF DISTRICT PLAN:
>SAMPLE ANALYSIS OF A DISTRICT PLAN
TITLE ENTERED:
'SAMPLE ANALYSIS OF A DISTRICT PLAN
```

Use a title which will help you to quickly identify the patrol operations plan being studied.

```
ENTER PATROL UNIT RESPONSE SPEED:
>?
TYPE THE RESPONSE SPEED OF THE PATROL UNIT IN MILES PER HOUR:
>20
PATROL UNIT RESPONSE SPEED ENTERED:  20.00

ENTER DISPATCH POLICY:
>?
THE FIVE TYPES OF PATROL UNIT DISPATCHING POLICY ARE
   SCM, MCM, ESCM, EMCM, AND AVL.  DO YOU WANT A MORE
   DETAILED EXPLANATION?:
>Y
```

"Y" may be used instead of "YES."

```
SCM (STRICT CENTER OF MASS):
CALL LOCATION:  ASSUMED AT CENTER OF DISTRICT BASED ON CALL
   FOR SERVICE STATISTICS.
UNIT LOCATION:  ASSUMED AT CENTER OF DISTRICT BASED ON PRE-
   VENTIVE PATROL COVERAGE.

ESTIMATED TRAVEL DISTANCE:  FROM DISTRICT CENTER(FOR UNIT)
   TO DISTRICT CENTER (FOR CALLS).

MCM (MODIFIED CENTER OF MASS):
CALL LOCATION:  ASSUMED AT CENTER OF REPORTING AREA.
UNIT LOCATION:  ASSUMED AT CENTER OF DISTRICT, BASED ON
   PREVENTIVE PATROL COVERAGES.
ESTIMATED TRAVEL DISTANCE: FROM DISTRICT CENTER (FOR UNIT)
   TO CENTER OF REPORTING AREA OF THE CALL.
```

This is the policy applicable to the sample analysis.

EMCM (EXPECTED MODIFIED CENTER OF MASS):
CALL LOCATION: ASSUMED AT CENTER OF REPORTING AREA.
UNIT LOCATION: CORRECTLY DISTRIBUTED OVER REPORTING AREAS ACCORDING TO PREVENTIVE PATROL COVERAGES.
ESTIMATED TRAVEL DISTANCE: STATISTICALLY AVERAGE TRAVEL DISTANCE FROM UNIT'S REPORTING AREA (WEIGHTED BY PREVENTIVE PATROL COVERAGE) TO REPORTING AREA OF THE CALL.

ESCM (EXPECTED STRICT CENTER OF MASS):
CALL LOCATION: ASSUMED DISTRIBUTED OVER REPORTING AREAS ACCORDING TO STATISTICAL PATTERNS FOR CALLS FOR SERVICE.
UNIT LOCATION: SAME AS FOR EMCM.
ESTIMATED TRAVEL DISTANCE: STATISTICALLY AVERAGE TRAVEL DISTANCE FROM UNIT'S REPORTING AREA (WEIGHTED BY PRE-VENTIVE PATROL COVERAGE) TO REPORTING AREA OF THE CALL (WEIGHTED BY THE CALL-FOR-SERVICE DISTRIBUTION).

AVL (AUTOMATIC VEHICLE LOCATION):
CALL LOCATION: ASSUMED AT CENTER OF REPORTING AREA.
UNIT LOCATION: ASSUMED TO BE KNOWN USING A PERFECT RESOLUTION VEHICLE LOCATION SYSTEM. THUS VEHICLE LOC-ATION IS AT CENTER OF ONE OF THE REPORTING AREAS OF ITS DISTRICT, THE PARTICULAR REPORTING AREA SELECTED PROBA-BALISTICALLY BASED ON PREVENTIVE PATROL COVERAGES.
ESTIMATED TRAVEL DISTANCE: EXACT TRAVEL DISTANCE FROM REAL-TIME REPORTING AREA OF THE UNIT TO THE REPORTING AREA OF THE CALL.

ENTER DISPATCH POLICY:
>SCM
DISPATCH POLICY ENTERED: SCM

NO SPECIAL PREFERENCE FOR DISTRICT UNIT.
CHANGE?:
>?
CURRENTLY NO SPECIAL PREFERENCE IS SHOWN FOR THE DISTRICT UNIT. DO YOU WANT TO CHANGE THIS SUCH THAT THE DISTRICT UNIT IS DISPATCHED FIRST WHEN IT IS AVAILABLE, REGARD-LESS OF OTHER FACTORS?:
>OK
PLEASE TYPE 'YES' OR 'NO': ←

An example of error correction by the program.

>Y
FIRST PREFERENCE FOR DISTRICT UNIT.

ZERO CAPACITY QUEUE. ←

A queue is a sequence of calls for service awaiting dispatch by a dispatcher.

CHANGE?:
>?
DO YOU WANT TO ASSUME THAT IF A CALL FOR SERVICE ARRIVES WHEN NO UNIT IS AVAILABLE FOR DISPATCH, THE CALL ENTERS A QUEUE TO WAIT FOR AN AVAILABLE UNIT?:
>NO
NO CHANGE.

```
IF YOU WANT                                         THEN TYPE

     ONLY EXACT STATISTICS                              0
     ONLY APPROXIMATE STATISTICS                        1
     BOTH EXACT AND APPROXIMATE STATISTICS              2
>?
TWO CLASSES OF STATISTICS CAN BE GENERATED, APPROXIMATE AND
   EXACT.  THE APPROXIMATE STATISTICS ARE NOT QUITE AS
   ACCURATE AS THE EXACT, BUT THEY COME VERY CLOSE AND ARE
   MUCH LESS EXPENSIVE.
     TYPE '0', '1', OR '2':
>1
ONLY APPROXIMATE STATISTICS WILL BE GENERATED.

TO DEFINE THE DISTRICT CONFIGURATION, ENTER THE NUMBERS OF
   THE UNITS AND THEIR ASSOCIATED REPORTING AREAS.

UNIT NUMBER:
>ONE
```

Note that larger problems cannot be handled using exact statistics -- see text for size limitations.

```
*** ERROR ***
THE STRING 'ONE' CAUSED AN ERROR, SINCE IT
   SHOULD HAVE BEEN A NUMBER.
   PLEASE RETYPE WHAT IT SHOULD HAVE BEEN:
>1

PPFS?:
>?

DO YOU WANT TO CHOOSE YOUR OWN SET OF PREVENTIVE PATROL
   FACTORS FOR THIS UNIT?:
>?


ASSOCIATED WITH EACH REPORTING AREA IN A DISTRICT MAY BE A
"PREVENTIVE PATROL FACTOR," ANY NUMBER BETWEEN 0.0 AND 10.0
WHICH INDICATES THE RELATIVE FRACTION OF PREVENTIVE
PATROL COVERAGE THAT A REPORTING AREA WILL RECEIVE.  A
REPORTING AREA WITH A FACTOR OF 0 RECEIVES NO PREVENTIVE
PATROL COVERAGE, ALTHOUGH CARS ARE STILL DISPATCHED TO THE
AREA WHEN CALLS FOR SERVICE COME IN.  THE PREVENTIVE PATROL
FACTOR IS STRICTLY RELATIVE -- IF ALL REPORTING AREAS
IN A DISTRICT HAVE THE SAME FACTOR, THEY WILL ALL RECEIVE
EQUAL PREVENTIVE PATROL COVERAGE REGARDLESS OF WHAT THAT
FACTOR IS.  EQUIVALENT EFFECTS CAN BE ACHIEVED BY INCREASING
THE FACTOR OF ONE REPORTING AREA IN A DISTRICT WHILE HOLDING
THE FACTORS OF ALL OTHER REPORTING AREAS IN THE DISTRICT
CONSTANT, OR BY HOLDING THAT ONE FACTOR CONSTANT AND REDUCING
ALL OTHERS IN THE DISTRICT.
(NOTE: IF PREVENTIVE PATROL FACTORS ARE SPECIFIED FOR A
DISTRICT, THE PREVENTIVE PATROL FACTOR FOR AT LEAST ONE
REPORTING AREA IN THE DISTRICT MUST BE NON-ZERO.)

THE PREVENTIVE PATROL FACTOR IS OPTIONAL.  IF YOU CHOOSE
   NOT TO USE THIS OPTION, PREVENTIVE PATROL WILL BE ASSUMED
   TO BE PROPORTIONAL TO NUMBER OF CALLS FOR SERVICE.
```

```
DO YOU WANT TO CHOOSE YOUR OWN SET OF PREVENTIVE PATROL
   FACTORS FOR THIS UNIT?:
>N

PPFS WILL BE PROPORTIONAL TO DEMAND FOR SERVICE.
REPORTING AREAS:
>?
TYPE THE NUMBER(S) OF THE REPORTING AREA(S) COVERED BY THE NEW UNIT.
THEY MAY BE SEPARATED BY BLANKS OR    COMMAS:
>121 131 141 151 161
$
MORE UNITS?:
>Y
```

Indicates that a unit of data processing costs has been expended to this point.

```
UNIT NUMBER:
>2

PPFS?:
>N

PPFS WILL BE PROPORTIONAL TO DEMAND FOR SERVICE.
REPORTING AREAS:
>71,81,91,101,111

MORE UNITS?:
>Y

UNIT NUMBER:
>3

PPFS?:
>NO

PPFS WILL BE PROPORTIONAL TO DEMAND FOR SERVICE.
REPORTING AREAS:
>11,21,31,41,51,61

MORE UNITS?:
>NO

ENTER PATROL UNIT SERVICE TIME (IN MINUTES):
>?
TYPE THE AVERAGE TIME THAT IT TAKES A PATROL UNIT TO
   COMPLETE A CALL FOR SERVICE:
>22
SERVICE TIME ENTERED:  22.0

ENTER NUMBER OF WORKLOAD LEVELS:
>?

YOU MAY WANT SEVERAL SETS OF STATISTICS GENERATED.  EACH
SET WILL CORRESPOND TO ONE WORKLOAD LEVEL (IN CALLS FOR
SERVICE PER HOUR) FOR THE ENTIRE REGION.   YOU WILL NEED
TO CHOOSE THREE THINGS:
```

```
    1)  THE LOWEST ARRIVAL RATE OF INTEREST OF CALLS FOR
        SERVICE PER HOUR.
    2)  AN INCREMENTAL ARRIVAL RATE OF CALLS FOR
        SERVICE PER HOUR.
    3)  THE NUMBER OF SETS OF STATISTICS THAT YOU WANT
        PRINTED OUT.
FOR EXAMPLE, IF YOU CHOOSE 6.0 AS YOUR LOWEST ARRIVAL RATE
AND 2.0 AS YOUR INCREMENTAL VALUE, AND YOU SPECIFY, SAY, 4
SETS OF TABLES; THEN TABLES WILL BE PRINTED OUT FOR CALL
RATES OF 6.0, 8.0, 10.0, AND 12.0 CALLS PER HOUR.
IF YOU ONLY WANT ONE SET OF STATISTICS, YOU NEED NOT
SPECIFY AN INCREMENTAL ARRIVAL RATE.

ENTER NUMBER OF WORKLOAD LEVELS:
>1
NUMBER OF WORKLOAD LEVELS ENTERED: 1

ENTER ARRIVAL RATE OF CALLS FOR SERVICE (NUMBER OF
   CALLS PER HOUR):
>6
ARRIVAL RATE ENTERED:  6.0
```

Analysis requires only one rate.

Printed automatically at this point.

```
      SUMMARY OF DISTRICT PLAN

NUMBER OF UNITS:          3
NUMBER OF REPORTING AREAS:        16
TITLE OF PLAN: SAMPLE ANALYSIS OF A DISTRICT PLAN
PATROL UNIT RESPONSE SPEED:  20.00
NUMBER OF WORKLOAD LEVELS:         1
PATROL UNIT SERVICE TIME:   22.0
NUMBER OF CALLS FOR SERVICE PER HOUR:    6.0
DISPATCH POLICY:  SCM
DISTRICT CAR FIRST.




ZERO CAPACITY QUEUE.
STATISTICS GENERATED:  ONLY APPROXIMATE STATISTICS


ALL REPORTING AREAS APPEAR IN AT LEAST ONE DISTRICT.

NO REPORTING AREAS APPEAR IN MORE THAN ONE DISTRICT.


ENTER COMMAND:
>PATROL
```

Used to enter cars' preventive patrol velocity and to request printing of preventive patrol passing frequencies in the output.

FOLLOW 'PATROL' BY THE EFFECTIVE PATROL SPEED.
E.G. 'PATROL 10.0'

Computer explains that command has not been properly entered.

NO PATROL CARD WILL BE ENTERED.

ENTER COMMAND:
>PATROL 10

PREVENTIVE PATROL SPEED:10.00

ENTER COMMAND:
>CORTM

Used to indicate that intra-reporting area travel times are to be based on area (square miles).

Computer explains that command has not been properly entered.

FOLLOW 'CORTM' BY THE PROPORTIONALITY CONSTANT.
E.G. 'CORTM .667'

NO CORTM CARD WILL BE ENTERED.

ENTER COMMAND:
>CORTM 0.90

CONSTANT OF PROPORTIONALITY: 0.900

ENTER COMMAND:
>GLOSSARY

Routine to specify terminology to be used in hypercube's output.

OPTION:
>?

THE FOLLOWING OPTIONS ARE AVAILABLE:
1. LIST THE GLOSSARY
2. ENTER OR CHANGE R_DIST
3. ENTER OR CHANGE ATOM
4. ENTER OR CHANGE R_UNIT
5. ENTER OR CHANGE T_COST
6. ENTER OR CHANGE CFS
7. ENTER OR CHANGE NM_DIST
8. ENTER OR CHANGE NM_UNIT
9. GO BACK TO COMMAND LEVEL

TYPE THE NUMBER (1-9) OF THE OPTION YOU WANT:
>1

Used to check if any terms have been previously specified.

IF NO "DEFINITION" HAS BEEN SUPPLIED, THE HYPERCUBE OUTPUT
WILL USE THE ONE LISTED IN THE USER'S MANUAL.
(SEE USER'S MANUAL, P. 39)

R_DIST: NO USER DEFINITION
ATOM: NO USER DEFINITION
R_UNIT: NO USER DEFINITION
T_COST: NO USER DEFINITION

```
   CFS:  NO USER DEFINITION
   NM_UNIT:  NO USER DEFINITION
   NM_DIST:  NO USER DEFINITION

OPTION:
>2

TYPE ( 8 CHARACTERS OR LESS) R_DIST:
>ZONE

R_DIST:  'ZONE    '

OPTION:
>3

TYPE ( 8 CHARACTERS OR LESS) ATOM:
>RPT BLOC

ATOM:  'RPT BLOC'

OPTION:
>4

TYPE (18 CHARACTERS OR LESS) R_UNIT:
>ZONE CAR

R_UNIT:  'ZONE CAR          '

OPTION:
>5

TYPE (18 CHARACTERS OR LESS) T_COST:
>TRAVEL TIME

T_COST:  'TRAVEL TIME       '

OPTION:
>6
$
TYPE (18 CHARACTERS OR LESS) CFS:
>INCIDENTS

CFS:  'INCIDENTS         '

OPTION:
>7

TYPE ( 8 CHARACTERS OR LESS) NM_UNIT:
>ZONE CAR

NM_UNIT:  'ZONE CAR' <----- Entry same as "R_UNIT."

OPTION:
>8

TYPE ( 8 CHARACTERS OR LESS) NM_DIST:   Entry same as "R_DIST"
>ZONE                           <-------
```

```
MM_DIST:  'ZONE

OPTION:
>9

ENTER COMMAND:
>PRINT_ALL

UNKNOWN COMMAND:  PRINT_ALL

ENTER COMMAND:
>PRNT_ALL  <----------
```

Requests printing of all output tables, often useful on a first run.

```
ALL HYPERCUBE STATISTICS WILL BE PRINTED.

ENTER COMMAND:
>PRNT_TR  <----------
```

Printing of the travel time matrix must be requested separately (not covered by PRNT_ALL)

```
TRAVEL MATRIX WILL BE PRINTED.

ENTER COMMAND:
>SAVE  <----------
```

Specification of the district plan and type of output desired is now complete.

```
DO YOU WANT TO COMPUTE THE OUTPUT MEASURES AT
THIS TIME?>Y
ENTER NAME OF REGION FILE (I.E., THE NAME OF THE FILE THAT
CONTAINS GEOGRAPHIC AND CALL VOLUME DATA FOR EACH REPORTING
AREA IN THE REGION OF INTEREST)>LAWCITY
ENTER NAME OF DISTRICT PLAN (I.E., THE NAME GIVEN TO THE DISTRICT
PLAN CREATED USING THE MONITNEW OR MONITOLD COMMAND)>DISTPLAN
ALL OUTPUT REQUESTED IN DISTPLAN CAN BE PRINTED AT YOUR TERMINAL
AS IT IS GENERATED BY THE HYPERCUBE PROGRAM, OR IT CAN BE
STORED FOR LATER RETRIEVAL. DO YOU WANT THE OUTPUT STORED?>NO
EXECUTION:
$
```

Output from hypercube analysis of the district plan follows.

CONTINUED

2 OF 3

INCIDENTS	DISTRIBUTION, BY RPT BLOC
11	0.14286
21	0.11429
31	0.06667
41	0.07619
51	0.09524
61	0.07619
71	0.07619
81	0.05714
91	0.02857
101	0.04762
111	0.02857
121	0.01905
131	0.00952
141	0.01905
151	0.04762
161	0.09524

This table appears in the output automatically only when a preventive patrol speed has been indicated in the district plan.

PATROL STREET MILES PER RPT BLOC	
11	5.20
21	3.70
31	3.20
41	4.80
51	5.00
61	2.40
71	2.90
81	3.60
91	2.90
101	4.10
111	3.80
121	2.70
131	1.50
141	2.30
151	4.30
161	3.20

TRAVEL TIME MATRIX: INTER-RPT BLOC

RPT BLOC NUMBER: ORIGIN	RPT BLOC NUMBER: DESTINATION 11	21	31	41	51	61	71
11	1.04	1.83	3.45	2.73	1.62	1.26	2.85
21	1.83	0.88	1.62	1.50	1.17	2.01	2.40
31	3.45	1.62	0.81	1.02	2.43	3.63	2.70
41	2.73	1.50	1.02	1.00	1.71	2.91	1.98
51	1.62	1.17	2.43	1.71	1.02	1.20	1.23
61	1.26	2.01	3.63	2.91	1.20	0.70	1.59
71	2.85	2.40	2.70	1.98	1.23	1.59	0.77
81	3.15	2.70	2.22	1.20	1.53	2.25	1.32
91	4.41	3.96	3.48	2.46	2.79	3.15	1.56
101	4.20	3.75	3.27	2.25	2.58	2.94	1.35
111	5.61	5.16	4.68	3.66	3.99	4.35	2.76
121	5.82	5.37	4.89	3.87	4.20	4.56	2.97
131	6.63	6.18	5.70	4.68	5.01	5.37	3.78
141	6.60	6.15	5.67	4.65	4.98	5.34	3.75
151	7.44	6.99	6.51	5.49	5.82	6.18	4.59
161	6.99	6.54	6.06	5.04	5.37	5.73	4.14

RPT BLOC NUMBER: ORIGIN	RPT BLOC NUMBER: DESTINATION 81	91	101	111	121	131	141
11	3.15	4.41	4.20	5.61	5.82	6.63	6.60
21	2.70	3.96	3.75	5.16	5.37	6.18	6.15
31	2.22	3.48	3.27	4.68	4.89	5.70	5.67
41	1.20	2.46	2.25	3.66	3.87	4.68	4.65
51	1.53	2.79	2.58	3.99	4.20	5.01	4.98
61	2.25	3.15	2.94	4.35	4.56	5.37	5.34
71	1.32	1.56	1.35	2.76	2.97	3.78	3.75
81	0.87	1.26	1.17	2.46	2.67	3.48	3.45
91	1.26	0.78	1.17	1.26	1.41	2.22	2.19
101	1.17	1.17	0.92	1.41	1.62	2.43	2.40
111	2.46	1.26	1.41	0.89	1.35	1.02	2.07
121	2.67	1.41	1.62	1.35	0.74	0.87	0.78
131	3.48	2.22	2.43	1.02	0.87	0.55	1.59
141	3.45	2.19	2.40	2.07	0.78	1.59	0.69
151	4.29	3.03	3.24	1.83	1.62	0.81	0.84
161	3.84	2.58	2.79	1.38	1.89	1.02	2.61

Matrix continues on next page.

RPT BLOC NUMBER: ORIGIN	RPT BLOC NUMBER: DESTINATION 151	161
11	7.44	6.99
21	6.99	6.54
31	6.51	6.06
41	5.49	5.04
51	5.82	5.37
61	6.18	5.73
71	4.59	4.14
81	4.29	3.84
91	3.03	2.58
101	3.24	2.79
111	1.83	1.38
121	1.62	1.89
131	0.81	1.02
141	0.84	2.61
151	0.95	1.77
161	1.77	0.81

MEAN TRAVEL TIMES FOR EACH ZONE CAR
TO EACH RPT BLOC

RPT BLOC ID NO	ID OF ZONE CAR ZONE CAR 1	ZONE CAR 2	ZONE CAR 3
11	6.93	3.71	1.83
21	6.48	3.26	1.49
31	6.00	3.03	2.31
41	4.98	2.11	1.91
51	5.31	2.09	1.48
61	5.67	2.54	1.82
71	4.08	1.35	2.19
81	3.78	1.31	2.30
91	2.52	1.28	3.51
101	2.73	1.21	3.30
111	1.54	2.01	4.71
121	1.55	2.25	4.92
131	0.99	2.92	5.73
141	1.74	3.02	5.70
151	1.41	3.73	6.54
161	1.35	3.28	6.09

STRICT CENTER-OF-MASS DISPATCHING

FIRST PREFERENCE ASSIGNED TO ZONE CAR
ASSOCIATED WITH EACH ZONE

ESTIMATED "COST" OF DISPATCHING I_TH ZONE CAR
TO J_TH RPT BLOC

RPT BLOC ID NO	ID OF ZONE CAR ZONE CAR 1	ZONE CAR 2	ZONE CAR 3
11	6.03	2.81	0.00
21	6.03	2.81	0.00
31	6.03	2.81	0.00
41	6.03	2.81	0.00
51	6.03	2.81	0.00
61	6.03	2.81	0.00
71	3.22	0.00	2.81
81	3.22	0.00	2.81
91	3.22	0.00	2.81
101	3.22	0.00	2.81
111	3.22	0.00	2.81
121	0.00	3.22	6.03
131	0.00	3.22	6.03
141	0.00	3.22	6.03
151	0.00	3.22	6.03
161	0.00	3.22	6.03

ZONE CAR SPATIAL ALLOCATION, WHILE AVAILABLE

RPT BLOC NO.	ID OF ZONE CAR ZONE CAR 1	ZONE CAR 2	ZONE CAR 3
11	0.00	0.00	0.25
21	0.00	0.00	0.20
31	0.00	0.00	0.12
41	0.00	0.00	0.13
51	0.00	0.00	0.17
61	0.00	0.00	0.13
71	0.00	0.32	0.00
81	0.00	0.24	0.00
91	0.00	0.12	0.00
101	0.00	0.20	0.00
111	0.00	0.12	0.00
121	0.10	0.00	0.00
131	0.05	0.00	0.00
141	0.10	0.00	0.00
151	0.25	0.00	0.00
161	0.50	0.00	0.00

PROBLEM TITLE: SAMPLE ANALYSIS OF A DISTRICT PLAN

* ITERATIVE APPROXIMATION METHOD USED *
NUMBER OF ITERATIONS REQUIRED: 4
NO QUEUING ALLOWED, BACK-UP SYSTEM FOR OVERFLOWS ASSUMED
RUN NUMBER: 1
ZONE CAR ...TOTAL NUMBER OF = 3
RPT BLOC ...TOTAL NUMBER OF = 16
AVERAGE SERVICE TIME= 22.00 MINUTES
AVERAGE NUMBER PER HOUR OF INCIDENTS = 6.000
AVERAGE NUMBER PER 22.00 MINUTES OF INCIDENTS = 2.200
SPEED OF PATROL= 10.00 MPH
AVERAGE UTILIZATION FACTOR
(IN THE CASE OF UNLIMITED LINE CAPACITY)= 0.733

REGION-WIDE AVERAGE TRAVEL TIME= 2.622 MINUTES
PROBABILITY OF SATURATION= 0.23999
REGION-WIDE AVERAGE WORKLOAD (% TIME BUSY)= 0.55734
STANDARD DEVIATION OF WORKLOAD= 0.070
MAXIMUM WORKLOAD IMBALANCE= 0.13678

FRACTION OF DISPATCHES THAT ARE INTER-ZONE = 0.44850

REGION-WIDE AVERAGE PATROL FREQUENCY= 0.268 PASSES PER HOUR

PERFORMANCE MEASURES THAT ARE SPECIFIC TO EACH ZONE CAR

ID OF ZONE CAR NAME	NO	WORKLOAD OF UNIT	% OF MEAN	FRACTION OF DISPATCHES OUT OF ZONE	% OF MEAN	AVERAGE TRAVEL TIME
ZONE CAR	1	0.480	86.1	.5511	122.9	3.510
ZONE CAR	2	0.575	103.2	.6124	136.5	2.354
ZONE CAR	3	0.617	110.7	.2124	47.4	2.172

PERFORMANCE MEASURES THAT ARE SPECIFIC TO EACH ZONE

ID OF ZONE NAME	NO	WORKLOAD OF ZONE	% OF MEAN	FRACTION OF DISPATCHES INTER-ZONE	% OF MEAN	AVERAGE TRAVEL TIME
ZONE	1	0.419	57.1	.3165	70.6	2.267
ZONE	2	0.524	71.4	.4405	98.2	2.119
ZONE	3	1.257	171.4	.4954	110.5	2.953

PERFORMANCE MEASURES THAT ARE SPECIFIC TO EACH RPT BLOC

ID # RPT BLOC	WORKLOAD OF RPT BLOC (#CALLS/100HR)	AVERAGE TRAVEL TIME	FREQUENCY OF PREVENTIVE PATROL PASSINGS (#/HOUR)
11	85.71	3.402	0.18
21	68.57	3.006	0.21
31	40.00	3.256	0.14
41	45.71	2.578	0.11
51	57.14	2.423	0.13
61	45.71	2.800	0.21
71	45.71	2.088	0.47
81	34.29	2.035	0.28
91	17.14	2.071	0.18
101	28.57	2.018	0.21
111	17.14	2.586	0.13
121	11.43	2.037	0.19
131	5.71	1.881	0.17
141	11.43	2.416	0.23
151	28.57	2.426	0.30
161	57.14	2.243	0.81

PERFORMANCE MEASURES THAT ARE SPECIFIC TO EACH RPT BLOC

ID # RPT BLOC	FRACTION OF INCIDENTS FROM RPT BLOC SERVICED BY UNIT NUMBER:		
	1	2	3
11	0.20	0.30	0.50
21	0.20	0.30	0.50
31	0.20	0.30	0.50
41	0.20	0.30	0.50
51	0.20	0.30	0.50
61	0.20	0.30	0.50
71	0.19	0.56	0.25
81	0.19	0.56	0.25
91	0.19	0.56	0.25
101	0.19	0.56	0.25
111	0.19	0.56	0.25
121	0.68	0.22	0.10
131	0.68	0.22	0.10
141	0.68	0.22	0.10
151	0.68	0.22	0.10
161	0.68	0.22	0.10

ALL DONE

```
CORE RESET TO 256
CSS.300 06/15/76
```

Core is automatically reset to 256 after output is printed. Don't forget to change it to 384 or more if further creation or modification of district files is to be carried out.

To illustrate the type of information produced by the monitor program for input to the hypercube program, the district file created for the sample analysis is listed below. Users of the "batch" hypercube program must format this information manually, without the monitor, and input it on punch cards.

```
11.40.45 >PRINTF DISTPLAN DATA

M =  3    R = 16    NUM = 1    ESTSTAT = 1    ;
'GLOSSARY'
R_DIST = 'ZONE      '
ATOM = 'RPT BLOC'
R_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'
'ATOM_NO'
'LAM'
'S'       1      5    121    131    141    151    161
'S'       2      5     71     81     91    101    111
'S'       3      6     11     21     31     41     51     61
'D_SCALE'   1.000
'SPEED'    20.00
'PATROL'       10.0
'TX'
'CORTM'     0.900

'SCM'
'FRST'
'SERVTM'      22.0

'RUN'  6.00    0.00
```

APPENDIX C

DISTRICT DESIGN EXERCISES

Exercise 1. MEASUREMENT OF GEOGRAPHIC DATA

Figure C-1 is a map of a sample police district. A coordinate system has been superimposed on the map with a distance scale (the unit of measure is miles). The police district is divided into 16 reporting areas. Using Figure C-1, locate the approximate geographic center of each reporting area, determine the x and y coordinates of each center, and estimate the approximate size in square miles of each reporting area. Record these measurements on the worksheet contained in Figure C-2. Also, approximate the number of patrolable street miles in each reporting area by multiplying its area, in square miles, by 35. Enter this information in the appropriate column in Figure C-2.

(The solution to this exercise is shown on page 176.)

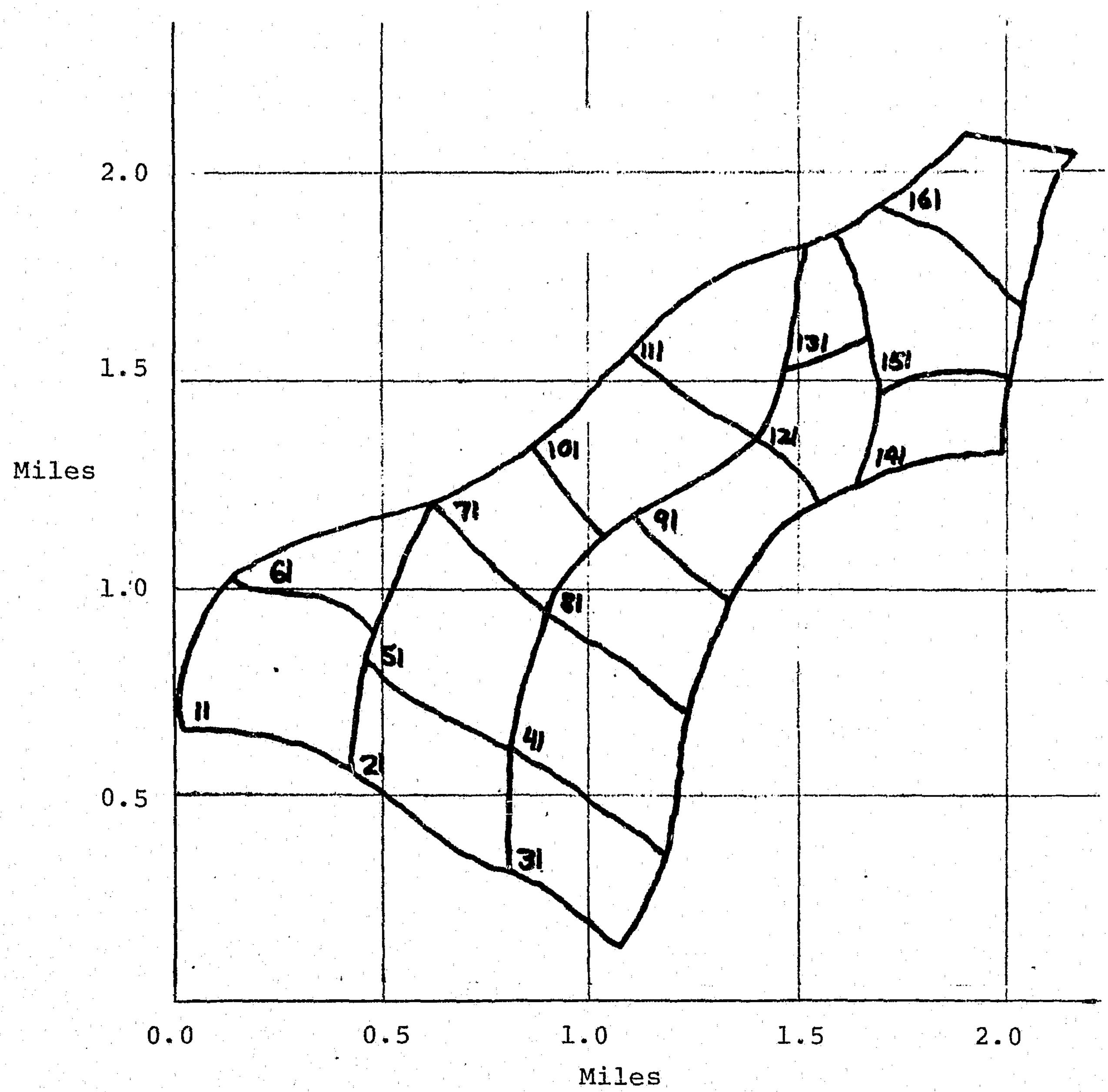


Figure C-1

MAP OF SAMPLE JURISDICTION

Reporting Area Number	X-coordinate	Y-coordinate	Size (sq. miles)	Calls for service	Est. street miles
11				105	
21				84	
31				49	
41				56	
51				70	
61				56	
71				56	
81				42	
91				21	
101				35	
111				21	
121				14	
131				7	
141				14	
151				35	
161				70	

Figure C-2

WORKSHEET FOR RECORDING GEOGRAPHIC AND CALL VOLUME DATA FOR THE SAMPLE REGION

Exercise 2. CREATION OF A REGION FILE

Using the data measured in Exercise 1, create a region file for the sample police region by following the procedure described in Chapter VI above. Include each of the following steps:

- input the data (give the file the name "LAWCITY");
- list the region file after all the data has been input;
- verify the accuracy of the entries in the file; and
- correct any errors.

```
CSS ONLINE - CHI1
```

Logging on.

```
>LINK M168 HYPER
PASSWORD:
88888888
A/C INFO:
>EXERCISES
M168 READY AT 16.56.28 ON   03NOV76
CSS.300 06/15/76
```

Data processing cost account is called "EXERCISES."

```
16.56.46 >NEWREG
ENTER NAME TO BE GIVEN TO THE REGION FILE BEING CREATED>LAWCITY
NEW FILE.
INPUT:
>     16
>   0011   0.25   0.80   0.148   105   5.2
>     21   0.63   0.57   0.106    84   3.7
>     31   0.98   0.38   0.090   49    3.2
>     41   1.03   0.67   0.138    56   4.8
>     51   0.69   0.90   0.142    70   5.0
>     61   0.43   1.04   0.068    56   2.4
>     71   0.85   1.15   0.082    56   2.9
>     81   1.12   0.98   0.104    42   3.6
>     91   1.33   1.19   0.084    21   2.9
>    101   1.10   1.35   0.116    35   4.1
>    111   1.32   1.60   0.108    21   3.8
>    121   1.58   1.41   0.076    14   2.7
>    131   1.57   1.69   0.042     7   1.5
>1   141   1.83   1.42   0.066    14   2.3
>    151   1.83   1.70   0.124    35   4.3
>    161   1.46   1.92   0.090    70   3.2
>
EDIT:
>FILE
```

Creation of a region file from scrat

Initial line indicates number of reporting areas. Each subsequent line gives a reporting area's identifying number and related data.

Signal that data for fina reporting area have been entered.

```
        16
      0011   0.25   0.80   0.148   105   5.2
        21   0.63   0.57   0.106    84   3.7
        31   0.98   0.38   0.090   49    3.2
        41   1.03   0.67   0.138    56   4.8
        51   0.69   0.90   0.142    70   5.0
        61   0.43   1.04   0.068    56   2.4
        71   0.85   1.15   0.082    56   2.9
        81   1.12   0.98   0.104    42   3.6
        91   1.33   1.19   0.084    21   2.9
       101   1.10   1.35   0.116    35   4.1
       111   1.32   1.60   0.108    21   3.8
       121   1.58   1.41   0.076    14   2.7
       131   1.57   1.69   0.042     7   1.5
  1    141   1.83   1.42   0.066    14   2.3
       151   1.83   1.70   0.124    35   4.3
       161   1.46   1.92   0.090    70   3.2
```

Listing of just created file for verification of entries. Note errors for reporting area 11, 31, 14

Routine for correcting individual lines in a region file.

```
17.22.02 >CORREG
ENTER NAME OF REGION FILE TO BE CHANGED>LAWCITY
EDIT:
>L $11$
   0011    0.25    0.80   0.148     105     5.2
>R          11     0.25     0.80   0.148     105      5.2
>L $31$
     31    0.98    0.38   0.090     49      3.2
>R          31     0.98     0.38   0.090      49      3.2
>L $1    141$
1    141    1.83    1.42   0.066     14      2.3
>R         141     1.83     1.42   0.066      14      2.3
>FILE
DO YOU WANT LAWCITY LISTED?>YES
```

Correct line for area 11.

Correct line for area 31.

Correct line for area 141.

16					
11	0.25	0.80	0.148	105	5.2
21	0.63	0.57	0.106	84	3.7
31	0.98	0.38	0.090	49	3.2
41	1.03	0.67	0.138	56	4.8
51	0.69	0.90	0.142	70	5.0
61	0.43	1.04	0.068	56	2.4
71	0.85	1.15	0.082	56	2.9
81	1.12	0.98	0.104	42	3.6
91	1.33	1.19	0.084	21	2.9
101	1.10	1.35	0.116	35	4.1
111	1.32	1.60	0.108	21	3.8
121	1.58	1.41	0.076	14	2.7
131	1.57	1.69	0.042	7	1.5
141	1.83	1.42	0.066	14	2.3
151	1.83	1.70	0.124	35	4.3
161	1.46	1.92	0.090	70	3.2

Exercise 3. CREATION OF A DISTRICT PLAN

Use the procedure described in Chapter VI to interactively enter patrol, dispatch, and district data into the computer. Use the region file created in Exercise 2, and the following information:

(1) Service time for calls (including travel time) averages 30 minutes per call.

(2) Calls for service for the entire region arrive at an average of three per hour.

(3) When responding to a call for service patrol cars travel at an average of 15 mph, but while engaged in preventive patrol they travel at an average of 7.5 mph.

(4) The terminology used to describe field operations in the department is (in terms of hypercube's terminology):

district = beat
unit = beat car
atom = reporting area
calls for service = calls for service
travel time = travel time

(5) Dispatch policy is approximately MCM. When the car assigned to a beat is available it is first choice for calls arriving in that beat. If no beat cars are available when a call arrives, the call is held by the dispatcher in a first-come-first-served queue until a car becomes available. In general, the dispatchers assign calls to the closest car (unless the assigned beat car is free, but is not the closest available car).

(6) The travel times associated with cars being dispatched to a call located in the same reporting area as the car was when it received the assignment should be approximated using the command CORTM = 0.667.

(7) When on preventive patrol the time spent by a beat car in any of the reporting areas in its beat is proportional to the workload in the reporting area.

(8) Three beats, covered by one car each, are to be used. Beat 1 contains reporting areas 11, 21, 51, 61, 71, and 101. Beat 2 contains areas 31, 41, 81, and 91. Beat 3 contains areas 111, 121, 131, 141, 151, and 161.

When the district plan has been entered into the computer use it to run a hypercube analysis which prints out all available output tables at your terminal but whose output is not stored in the computer for later use.

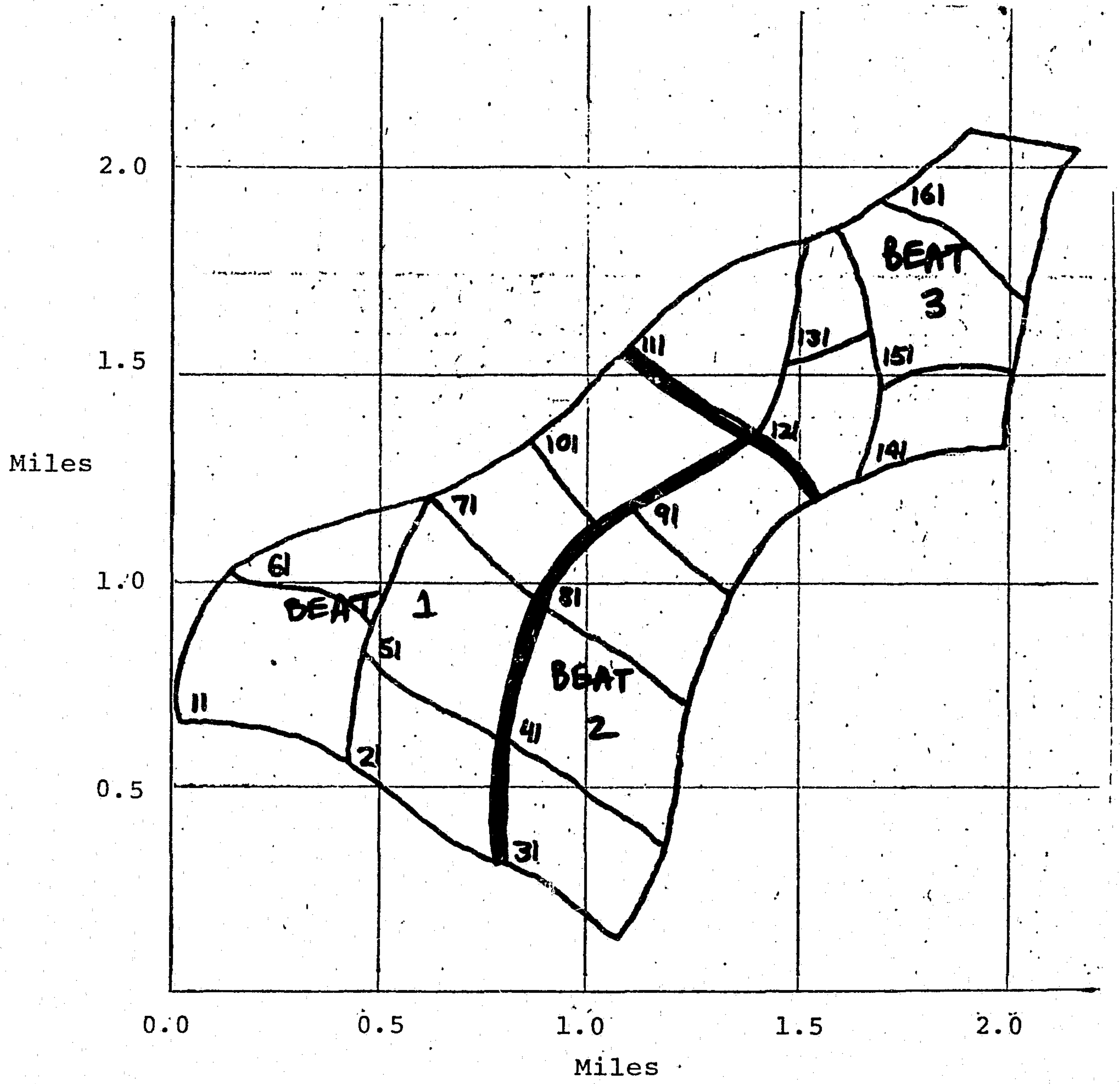


Figure C-3

MAP OF SAMPLE JURISDICTION

```
11.42.26 >SET CORE 384
CSS.300 06/15/76

11.49.02 >MONITNEW
ENTER NAME OF REGION FILE (I.E., THE NAME OF THE FILE THAT
CONTAINS GEOGRAPHIC AND CALL VOLUME DATA FOR EACH REPORTING
AREA IN THE REGION OF INTEREST)>LAW CITY
LAW DOES NOT EXIST, ENTER NAME OF REGION FILE>LAWCITY
ENTER NAME TO BE GIVEN TO THE NEW DISTRICT PLAN BEING CREATED>E/3
EXECUTION:




NSF/RANN INTERACTIVE HYPERCUBE SYSTEM

MONITOR HERE.  WHEN IN DOUBT, TYPE '?' .

THE INTERACTIVE MONITOR USES SPECIFIC TERMS TO REFER TO
RESPONSE UNITS, CALLS FOR SERVICE, ETC. WHICH MAY BE
DIFFERENT FROM THOSE YOU ARE ACCUSTOMED TO.  WHILE THIS
TERMINOLOGY CANNOT BE MODIFIED WITHIN THE MONITOR ITSELF,
IT IS POSSIBLE TO PROVIDE YOUR OWN TERMS TO BE USED IN THE
FINAL HYPERCUBE OUTPUT BY USING THE "GLOSSARY" COMMAND
AFTER FIRST CREATING YOUR DISTRICT PLAN.  DO YOU WANT AN
EXPLANATION OF THE TERMINOLOGY BEING USED BY THE MONITOR?:
>N


ENTER COMMAND:
>CREATE

ENTER TITLE OF DISTRICT PLAN:
>EXERCISE 3 - 3 CARS IN LAWCITY
TITLE ENTERED:
'EXERCISE 3 - 3 CARS IN LAWCITY

ENTER PATROL UNIT RESPONSE SPEED:
>15
PATROL UNIT RESPONSE SPEED ENTERED:  15.00

ENTER DISPATCH POLICY:
>MCM
DISPATCH POLICY ENTERED:  MCM

NO SPECIAL PREFERENCE FOR DISTRICT UNIT.
CHANGE?:
>Y
FIRST PREFERENCE FOR DISTRICT UNIT.
```

```
ZERO CAPACITY QUEUE.
CHANGE?:
>Y
INFINITE CAPACITY QUEUE .


IF YOU WANT                                         THEN TYPE
     ONLY EXACT STATISTICS                               0
     ONLY APPROXIMATE STATISTICS                         1
     BOTH EXACT AND APPROXIMATE STATISTICS               2
>1
ONLY APPROXIMATE STATISTICS WILL BE GENERATED.

TO DEFINE THE DISTRICT CONFIGURATION, ENTER THE NUMBERS OF
   THE UNITS AND THEIR ASSOCIATED REPORTING AREAS.

UNIT NUMBER:
>1

PPFS?:
>N

PPFS WILL BE PROPORTIONAL TO DEMAND FOR SERVICE.
REPORTING AREAS:
>11,21,51,61,71,101

MORE UNITS?:
>Y

UNIT NUMBER:
>2

PPFS?:
>N

PPFS WILL BE PROPORTIONAL TO DEMAND FOR SERVICE.
REPORTING AREAS:
>31,41,91,81,







MORE UNITS?:
>Y

UNIT NUMBER:
>3

PPFS?:
>N
```

```
PPFS WILL BE PROPORTIONAL TO DEMAND FOR SERVICE.
REPORTING AREAS:
>161 151 141 131 121 111

MORE UNITS?:
>N

ENTER PATROL UNIT SERVICE TIME (IN MINUTES):
>30
SERVICE TIME ENTERED:  30.0

ENTER NUMBER OF WORKLOAD LEVELS:
>1
NUMBER OF WORKLOAD LEVELS ENTERED: 1

ENTER ARRIVAL RATE OF CALLS FOR SERVICE (NUMBER OF
   CALLS PER HOUR):
>3.00
ARRIVAL RATE ENTERED:  3.0


      SUMMARY OF DISTRICT PLAN

NUMBER OF UNITS:          3
NUMBER OF REPORTING AREAS:        16
TITLE OF PLAN: EXERCISE 3 - 3 CARS IN LAWCITY
PATROL UNIT RESPONSE SPEED:  15.00
NUMBER OF WORKLOAD LEVELS:         1
PATROL UNIT SERVICE TIME:   30.0
NUMBER OF CALLS FOR SERVICE PER HOUR:     3.0
DISPATCH POLICY:  MCM
DISTRICT CAR FIRST.
INFINITE CAPACITY QUEUE.
STATISTICS GENERATED:  ONLY APPROXIMATE STATISTICS


ALL REPORTING AREAS APPEAR IN AT LEAST ONE DISTRICT.

NO REPORTING AREAS APPEAR IN MORE THAN ONE DISTRICT.


ENTER COMMAND:
>PATROL

FOLLOW 'PATROL' BY THE EFFECTIVE PATROL SPEED.
E.G.  'PATROL 10.0'

NO PATROL CARD WILL BE ENTERED.


ENTER COMMAND:
>PATROL 7.5

PREVENTIVE PATROL SPEED: 7.50
```

```
ENTER COMMAND:
>CORTM 0.667

CONSTANT OF PROPORTIONALITY: 0.667





ENTER COMMAND:
>GLOSSARY

OPTION:
>2

TYPE ( 8 CHARACTERS OR LESS) R_DIST:
>BEAT

R_DIST:  'BEAT    '

OPTION:
>3

TYPE ( 8 CHARACTERS OR LESS) ATOM:
>RPT AREA

ATOM:  'RPT AREA'

OPTION:
>4

TYPE (18 CHARACTERS OR LESS) R_UNIT:
>BEAR?BEAT CAR

R_UNIT:  'BEAT CAR          '

OPTION:
>6

TYPE (18 CHARACTERS OR LESS) CFS:
>CALLS FOR SERVICE

CFS:  'CALLS FOR SERVICE '

OPTION:
>7

TYPE ( 8 CHARACTERS OR LESS) NM_UNIT:
>BEAT CAR

NM_UNIT:  'BEAT CAR'

OPTION:
>8

TYPE ( 8 CHARACTERS OR LESS) NM_DIST:
>BEAT
```

```
NM_DIST:   'BEAT

OPTION:
>9


ENTER COMMAND:
>PRINTALL@PRNT_ALL

ALL HYPERCUBE STATISTICS WILL BE PRINTED.


ENTER COMMAND:
>PRNT_TR


TRAVEL MATRIX WILL BE PRINTED.


ENTER COMMAND:
>SAVE

DO YOU WANT TO COMPUTE THE OUTPUT MEASURES AT
THIS TIME?>Y
ENTER NAME OF REGION FILE (I.E., THE NAME OF THE FILE THAT
CONTAINS GEOGRAPHIC AND CALL VOLUME DATA FOR EACH REPORTING
AREA IN THE REGION OF INTEREST)>LAWCITY
ENTER NAME OF DISTRICT PLAN (I.E., THE NAME GIVEN TO THE DISTRICT
PLAN CREATED USING THE MONITNEW OR MONITOLD COMMAND)>EX3
ALL OUTPUT REQUESTED IN EX3 CAN BE PRINTED AT YOUR TERMINAL
AS IT IS GENERATED BY THE HYPERCUBE PROGRAM, OR IT CAN BE
STORED FOR LATER RETRIEVAL. DO YOU WANT THE OUTPUT STORED?>N
EXECUTION:
$


    CALLS FOR SERVICE  DISTRIBUTION, BY RPT AREA
           11          0.14286
           21          0.11429
           31          0.06667
           41          0.07619
           51          0.09524
           61          0.07619
           71          0.07619
           81          0.05714
           91          0.02857
          101          0.04762
          111          0.02857
          121          0.01905
          131          0.00952
          141          0.01905
          151          0.04762
          161          0.09524
```

PATROL STREET MILES PER RPT AREA

11	5.20
21	3.70
31	3.20
41	4.80
51	5.00
61	2.40
71	2.90
81	3.60
91	2.90
101	4.10
111	3.80
121	2.70
131	1.50
141	2.30
151	4.30
$ 161	3.20

TRAVEL TIME MATRIX: INTER-RPT AREA

RPT AREA NUMBER: ORIGIN	RPT AREA NUMBER: DESTINATION						
	11	21	31	41	51	61	71
11	1.03	2.44	4.60	3.64	2.16	1.68	3.80
21	2.44	0.87	2.16	2.00	1.56	2.68	3.20
31	4.60	2.16	0.80	1.36	3.24	4.84	3.60
41	3.64	2.00	1.36	0.99	2.28	3.88	2.64
51	2.16	1.56	3.24	2.28	1.01	1.60	1.64
61	1.68	2.68	4.84	3.88	1.60	0.70	2.12
71	3.80	3.20	3.60	2.64	1.64	2.12	0.76
81	4.20	3.60	2.96	1.60	2.04	3.00	1.76
91	5.88	5.28	4.64	3.28	3.72	4.20	2.08
101	5.60	5.00	4.36	3.00	3.44	3.92	1.80
111	7.43	6.88	6.24	4.88	5.32	5.80	3.68
121	7.76	7.16	6.52	5.16	5.60	6.08	3.96
131	8.84	8.24	7.60	6.24	6.68	7.16	5.04
141	8.80	8.20	7.56	6.20	6.64	7.12	5.00
151	9.92	9.32	8.68	7.32	7.76	8.24	6.12
161	9.32	8.72	8.08	6.72	7.16	7.64	5.52

RPT AREA NUMBER: ORIGIN	RPT AREA NUMBER: DESTINATION 81	91	101	111	121	131	141
11	4.20	5.88	5.60	7.48	7.76	8.84	8.80
21	3.60	5.28	5.00	6.88	7.16	8.24	8.20
31	2.96	4.64	4.36	6.24	6.52	7.60	7.56
41	1.60	3.28	3.00	4.88	5.16	6.24	6.20
51	2.04	3.72	3.44	5.32	5.60	6.68	6.64
61	3.00	4.20	3.92	5.80	6.08	7.16	7.12
71	1.76	2.08	1.80	3.68	3.96	5.04	5.00
81	0.86	1.68	1.56	3.28	3.56	4.64	4.60
91	1.68	0.77	1.56	1.68	1.88	2.96	2.92
101	1.56	1.56	0.91	1.88	2.16	3.24	3.20
111	3.28	1.68	1.88	0.88	1.80	1.36	2.76
121	3.56	1.88	2.16	1.80	0.74	1.16	1.04
131	4.64	2.96	3.24	1.36	1.16	0.55	2.12
141	4.60	2.92	3.20	2.76	1.04	2.12	0.69
151	5.72	4.04	4.32	2.44	2.16	1.08	1.12
161	5.12	3.44	3.72	1.84	2.52	1.36	3.48

RPT AREA NUMBER: ORIGIN	RPT AREA NUMBER: DESTINATION 151	161
11	9.92	9.32
21	9.32	8.72
31	8.68	8.08
41	7.32	6.72
51	7.76	7.16
61	8.24	7.64
71	6.12	5.52
81	5.72	5.12
91	4.04	3.44
101	4.32	3.72
111	2.44	1.84
121	2.16	2.52
131	1.08	1.36
141	1.12	3.48
151	0.94	2.36
161	2.36	0.80

MEAN TRAVEL TIMES FOR EACH BEAT CAR
TO EACH RPT AREA

RPT AREA ID NO	ID OF BEAT CAR BEAT CAR 1	BEAT CAR 2	BEAT CAR 3
11	2.38	4.34	9.01
21	2.32	2.86	8.41
31	3.74	2.01	7.77
41	2.91	1.54	6.41
51	1.80	2.68	6.85
61	1.99	3.98	7.33
71	2.48	2.63	5.21
81	2.97	1.82	4.81
91	4.26	2.96	3.14
101	3.94	2.86	3.41
111	5.74	4.48	1.90
121	6.02	4.75	2.00
131	7.10	5.83	1.31
141	7.06	5.79	2.36
151	8.18	6.91	1.88
161	7.58	6.31	1.68

MODIFIED CENTER-OF-MASS DISPATCHING

FIRST PREFERENCE ASSIGNED TO BEAT CAR
ASSOCIATED WITH EACH BEAT

ESTIMATED "COST" OF DISPATCHING I_TH BEAT CAR
TO J_TH RPT AREA

RPT AREA ID NO	ID OF BEAT CAR BEAT CAR 1	BEAT CAR 2	BEAT CAR 3
11	0.00	3.59	9.01
21	0.00	2.41	8.41
31	3.65	0.00	7.77
41	2.69	0.00	6.41
51	0.00	2.23	6.85
61	0.00	3.83	7.33
71	0.00	2.59	5.21
81	2.46	0.00	4.81
91	4.14	0.00	3.13
101	0.00	2.59	3.41
111	5.74	4.47	0.00
121	6.02	4.75	0.00
131	7.10	5.83	0.00
141	7.06	5.79	0.00
151	8.18	6.91	0.00
161	7.58	6.31	0.00

BEAT CAR SPATIAL ALLOCATION, WHILE AVAILABLE

RPT AREA NO.	ID OF BEAT CAR BEAT CAR 1	BEAT CAR 2	BEAT CAR 3
11	0.26	0.00	0.00
21	0.21	0.00	0.00
31	0.00	0.29	0.00
41	0.00	0.33	0.00
51	0.17	0.00	0.00
61	0.14	0.00	0.00
71	0.14	0.00	0.00
81	0.00	0.25	0.00
91	0.00	0.13	0.00
101	0.09	0.00	0.00
111	0.00	0.00	0.13
121	0.00	0.00	0.09
131	0.00	0.00	0.04
141	0.00	0.00	0.09
151	0.00	0.00	0.22
161	0.00	0.00	0.43

PROBLEM TITLE: EXERCISE 3 - 3 CARS IN LAWCITY

* ITERATIVE APPROXIMATION METHOD USED *
NUMBER OF ITERATIONS REQUIRED: 4
UNLIMITED CAPACITY QUEUE WITH 1_ST-COME 1_ST-SERVED QUEUE DISCIPLINE
RUN NUMBER: 1
BEAT CAR ...TOTAL NUMBER OF = 3
RPT AREA ...TOTAL NUMBER OF = 16
AVERAGE SERVICE TIME= 30.00 MINUTES
AVERAGE NUMBER PER HOUR OF CALLS FOR SERVICE = 3.000
AVERAGE NUMBER PER 30.00 MINUTES OF CALLS FOR SERVICE = 1.500
SPEED OF PATROL= 7.50 MPH
AVERAGE UTILIZATION FACTOR
(IN THE CASE OF UNLIMITED LINE CAPACITY)= 0.500

REGION-WIDE AVERAGE TRAVEL TIME= 3.358 MINUTES

AVERAGE TRAVEL TIME FOR QUEUED CALLS= 4.111 MINUTES
PROBABILITY OF SATURATION= 0.23684
REGION-WIDE AVERAGE WORKLOAD (% TIME BUSY)= 0.50000
STANDARD DEVIATION OF WORKLOAD= 0.057
MAXIMUM WORKLOAD IMBALANCE= 0.11321

FRACTION OF DISPATCHES THAT ARE INTER-BEAT = 0.43879

REGION-WIDE AVERAGE PATROL FREQUENCY= 0.223 PASSES PER HOUR

PERFORMANCE MEASURES THAT ARE SPECIFIC TO EACH BEAT CAR

NAME	ID OF BEAT CAR NO	WORKLOAD OF UNIT	% OF MEAN	FRACTION OF DISPATCHES OUT OF BEAT	% OF MEAN	AVERAGE TRAVEL TIME
BEAT CAR	1	0.553	110.6	.2219	50.6	2.975
BEAT CAR	2	0.507	101.4	.6149	140.1	3.302
BEAT CAR	3	0.440	88.0	.5121	116.7	3.926

PERFORMANCE MEASURES THAT ARE SPECIFIC TO EACH BEAT

NAME	ID OF BEAT NO	WORKLOAD OF BEAT	% OF MEAN	FRACTION OF DISPATCHES INTER-BEAT	% OF MEAN	AVERAGE TRAVEL TIME
BEAT	1	0.829	165.7	.4737	108.0	3.399
BEAT	2	0.343	68.6	.4280	97.5	2.955
BEAT	3	0.329	65.7	.3613	82.3	3.681

PERFORMANCE MEASURES THAT ARE SPECIFIC TO EACH RPT AREA

ID # RPT AREA	WORKLOAD OF RPT AREA (#CALLS/100HR)	AVERAGE TRAVEL TIME	FREQUENCY OF PREVENTIVE PATROL PASSINGS (#/HOUR)
11	42.86	3.950	0.17
21	34.29	3.430	0.19
31	20.00	3.407	0.34
41	22.86	2.693	0.26
51	28.57	2.833	0.12
61	22.86	3.362	0.19
71	22.86	2.954	0.16
81	17.14	2.624	0.26
91	8.57	3.259	0.16
101	14.29	3.573	0.07
111	8.57	3.136	0.14
121	5.71	3.306	0.14
131	2.86	3.302	0.12
141	5.71	3.927	0.16
151	14.29	4.069	0.21
161	28.57	3.715	0.57

PERFORMANCE MEASURES THAT ARE SPECIFIC TO EACH RPT AREA

ID # RPT AREA	FRACTION OF CALLS FOR SERVICE FROM RPT AREA SERVICED BY UNIT NUMBER: 1	2	3
11	0.53	0.29	0.19
21	0.53	0.29	0.19
31	0.25	0.57	0.18
41	0.25	0.57	0.18
51	0.53	0.29	0.19
61	0.53	0.29	0.19
71	0.53	0.29	0.19
81	0.25	0.57	0.18
91	0.14	0.57	0.29
101	0.53	0.29	0.19
111	0.13	0.23	0.64
121	0.13	0.23	0.64
131	0.13	0.23	0.64
141	0.13	0.23	0.64
151	0.13	0.23	0.64
161	0.13	0.23	0.64

ALL DONE

CORE RESET TO 256
CSS.300 06/15/76

Exercise 4. IMPROVING PERFORMANCE OF A DISTRICT PLAN

Use the results of exercise 3 to redesign the initial district plan to correct for imbalances in average travel times to calls arriving in each of the three beats (i.e., travel time as seen by the citizen requesting service). Do this by relocating a single reporting area, rerunning the hypercube analysis, relocating a second reporting area based on the new output, and rerunning the program once more. Cancel printing of all but car and beat statistics, and do not store the output in the computer.

Next attempt to create a better workload balance among the three cars by an additional change to the district plan. Do this by relocating a single reporting area and running the program once again. Note the impact of your change on both workload balance and the travel time balance sought earlier in the exercise.

```
12.19.50 >SET CORE 384
CSS.300 06/15/76
```

Increase core to permit modification of a district plan.

```
12.20.11 >MONITOLD
ENTER NAME OF DISTRICT PLAN TO BE MODIFIED (I.E., THE NAME
OF A DISTRICT PLAN PREVIOUSLY CREATED USING THE MONITNEW OR
MONITOLD COMMAND)>EX3
/|ENTER NAME OF REGION FILE (I.E., THE NAME OF THE FILE THAT
CONTAINS GEOGRAPHIC AND CALL VOLUME DATA FOR EACH REPORTING
AREA IN THE REGION OF INTEREST)>LAWCITY
ENTER NAME TO BE GIVEN TO THE NEW DISTRICT PLAN BEING CREATED>EX4A
EXECUTION:
```

The modified district plan must have its own name, different from that of the original plan. Here "EX4A" is used.

```
NSF/RANN INTERACTIVE HYPERCUBE SYSTEM

MONITOR HERE.  WHEN IN DOUBT, TYPE '?' .

THE INTERACTIVE MONITOR USES SPECIFIC TERMS TO REFER TO
RESPONSE UNITS, CALLS FOR SERVICE, ETC. WHICH MAY BE
DIFFERENT FROM THOSE YOU ARE ACCUSTOMED TO.  WHILE THIS
TERMINOLOGY CANNOT BE MODIFIED WITHIN THE MONITOR ITSELF,
IT IS POSSIBLE TO PROVIDE YOUR OWN TERMS TO BE USED IN THE
FINAL HYPERCUBE OUTPUT BY USING THE "GLOSSARY" COMMAND
AFTER FIRST CREATING YOUR DISTRICT PLAN.  DO YOU WANT AN
EXPLANATION OF THE TERMINOLOGY BEING USED BY THE MONITOR?:
>NO


ENTER COMMAND:
>TITLE
```

Revise the previous title.

```
TITLE OF PLAN:  'EXERCISE 3 - 3 CARS IN LAWCITY
CHANGE?:
>Y

ENTER TITLE OF DISTRICT PLAN:
>EXERCISE 4 - BALANCE TRAV TIME FOR EX3, 1ST TRY
TITLE ENTERED:
'EXERCISE 4 - BALANCE TRAV TIME FOR EX3, 1ST TRY     '


ENTER COMMAND:
>CONFIG
```

Permits revision of reporting area makeup of beats.

```
DO YOU WANT THE DISTRICT CONFIGURATION PRINTED OUT?:
>YES
```

```
DISTRICT          REPORTING AREAS

     1                 11      21      51      61      71      101

     2                 31      41      81      91

     3                111     121     131     141     151      161

DO YOU WANT TO MODIFY THE DISTRICT CONFIGURATION?:
>Y
OPTION:
>?
THE FOLLOWING OPTIONS ARE AVAILABLE:
   1) ADD A NEW UNIT
   2) REMOVE A UNIT
   3) NOT IMPLEMENTED IN CURRENT VERSION
   4) ADD ONE OR MORE REPORTING AREAS TO A DISTRICT
   5) SUBTRACT ONE OR MORE REPORTING AREAS FROM A DISTRICT
   6) MOVE ONE OR MORE REPORTING AREAS FROM ONE DISTRICT TO
      ANOTHER
   7) COMBINE TWO DISTRICTS
   8) NOT IMPLEMENTED IN CURRENT VERSION
   9) PRINT THE DISTRICT CONFIGURATION
TYPE THE NUMBER OF THE OPTION (1 -  9) THAT YOU WISH
   TO USE:
>6

ENTER NUMBER OF DISTRICT
 FROM WHICH YOU ARE SUBTRACTING:
>3

ENTER NUMBER OF DISTRICT
```

Refer to output shown on page 189 to determine the average travel times for calls arising in each beat. Note that the average is highest in beat 3 and lowest in beat 2. This suggests that 121 should be moved from 3 to 2 (see map).

```
 TO WHICH YOU ARE ADDING:
>2
TYPE LIST OF REPORTING AREAS TO BE MOVED FROM DISTRICT
     3 TO DISTRICT      2:
>121

MORE CHANGES?:
>N

ALL REPORTING AREAS APPEAR IN AT LEAST ONE DISTRICT.

NO REPORTING AREAS APPEAR IN MORE THAN ONE DISTRICT.

ENTER COMMAND:
>PRNT_ATOM
```

This and subsequent "PRNT_XX..." commands are used to cancel output of detailed tables now no longer desired. Only car and beat statistics will be required.

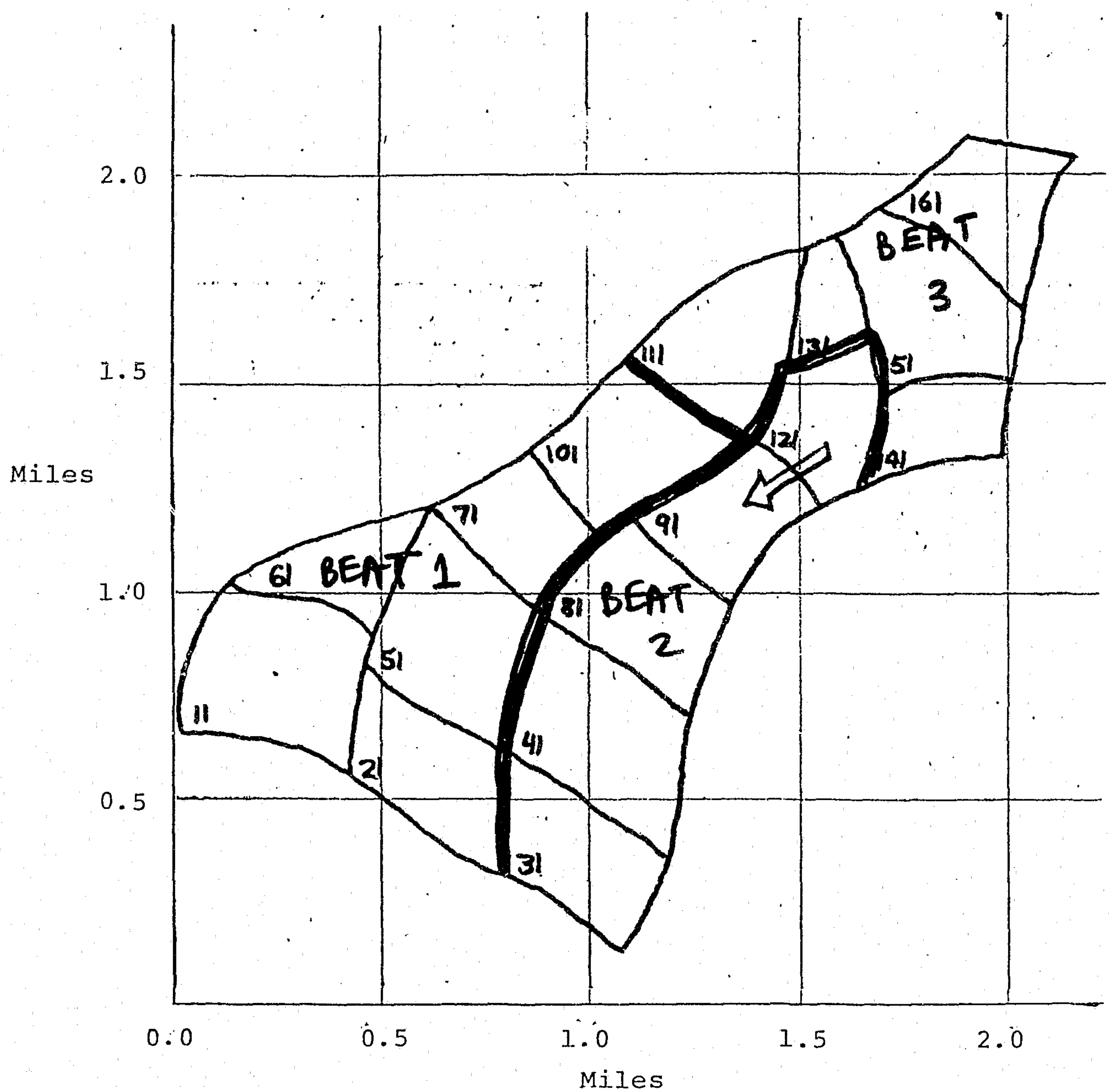


Figure C-4

MAP OF SAMPLE JURISDICTION

```
ATOM SPECIFIC DATA WILL NOT BE PRINTED.


ENTER COMMAND:
>PRNT_CFS


CALLS FOR SERVICE DATA WILL NOT BE PRINTED.


ENTER COMMAND:
>PP#RNT_COST


COST MATRIX WILL NOT BE PRINTED.


ENTER COMMAND:
>PRNT_SP_ALC


RESPONSE UNIT SPATIAL ALLOCATION DATA WILL NOT BE PRINTED.


ENTER COMMAND:
>PRNT_TR


TRAVEL MATRIX WILL NOT BE PRINTED.


ENTER COMMAND:
>PRNT_TT


TRAVEL TIMES TO EACH ATOM WILL NOT BE PRINTED.


ENTER COMMAND:
>PRNT_PATROL


PATROL STREET MILES PER ATOM WILL NOT BE PRINTED.




ENTER COMMAND:
>SAVE
```

← Specification of modified district plan and of desired output is complete.

DO YOU WANT TO COMPUTE THE OUTPUT MEASURES AT
THIS TIME?>yes
ALL OUTPUT REQUESTED IN EX4A CAN BE PRINTED AT YOUR TERMINAL
AS IT IS GENERATED BY THE HYPERCUBE PROGRAM, OR IT CAN BE
STORED FOR LATER RETRIEVAL. DO YOU WANT THE OUTPUT STORED?>no
$EXECUTION:

MODIFIED CENTER-OF-MASS DISPATCHING

FIRST PREFERENCE ASSIGNED TO BEAT CAR
ASSOCIATED WITH EACH BEAT
PROBLEM TITLE: EXERCISE 4 - BALANCE TRAV TIME FOR EX3, 1ST TRY

* ITERATIVE APPROXIMATION METHOD USED *
NUMBER OF ITERATIONS REQUIRED: 4
UNLIMITED CAPACITY QUEUE WITH 1_ST-COME 1_ST-SERVED QUEUE DISCIPLINE
RUN NUMBER: 1
BEAT CAR ...TOTAL NUMBER OF = 3
RPT AREA ...TOTAL NUMBER OF = 16
AVERAGE SERVICE TIME= 30.00 MINUTES
AVERAGE NUMBER PER HOUR OF CALLS FOR SERVICE = 3.000
AVERAGE NUMBER PER 30.00 MINUTES OF CALLS FOR SERVICE = 1.500
SPEED OF PATROL= 7.50 MPH
AVERAGE UTILIZATION FACTOR
(IN THE CASE OF UNLIMITED LINE CAPACITY)= 0.500

REGION-WIDE AVERAGE TRAVEL TIME= 3.423 MINUTES

AVERAGE TRAVEL TIME FOR QUEUED CALLS= 4.111 MINUTES
PROBABILITY OF SATURATION= 0.23684
REGION-WIDE AVERAGE WORKLOAD (% TIME BUSY)= 0.50000
STANDARD DEVIATION OF WORKLOAD= 0.060
MAXIMUM WORKLOAD IMBALANCE= 0.11843

FRACTION OF DISPATCHES THAT ARE INTER-BEAT = 0.44040

REGION-WIDE AVERAGE PATROL FREQUENCY= 0.225 PASSES PER HOUR

PERFORMANCE MEASURES THAT ARE SPECIFIC TO EACH BEAT CAR

ID OF BEAT CAR NAME	NO	WORKLOAD OF UNIT	% OF MEAN	FRACTION OF DISPATCHES OUT OF BEAT	% OF MEAN	AVERAGE TRAVEL TIME
BEAT CAR	1	0.553	110.7	.2228	50.6	2.975
BEAT CAR	2	0.512	102.4	.5906	134.1	3.432
BEAT CAR	3	0.435	87.0	.5450	123.7	4.007

PERFORMANCE MEASURES THAT ARE SPECIFIC TO EACH BEAT

ID OF BEAT NAME	NO	WORKLOAD OF BEAT	% OF MEAN	FRACTION OF DISPATCHES INTER-BEAT	% OF MEAN	AVERAGE TRAVEL TIME
BEAT	1	0.829	165.7	.4740	107.6	3.463
BEAT	2	0.371	74.3	.4326	98.2	3.169
BEAT	3	0.300	60.0	.3564	80.9	3.634

ALL DONE

Note the improvement, compared to p. 189, in average travel times for beats.

CORE RESET TO 256
CSS.300 06/15/76

12.34.44 >MONITOLD ← Begin additional change of district plan.
ENTER NAME OF DISTRICT PLAN TO BE MODIFIED (I.E., THE NAME
OF A DISTRICT PLAN PREVIOUSLY CREATED USING THE MONITNEW OR
MONITOLD COMMAND)>ex4a
ENTER NAME OF REGION FILE (I.E., THE NAME OF THE FILE THAT
CONTAINS GEOGRAPHIC AND CALL VOLUME DATA FOR EACH REPORTING
AREA IN THE REGION OF INTEREST)>lawcity
ENTER NAME TO BE GIVEN TO THE NEW DISTRICT PLAN BEING CREATED>ex4b
NOT ENOUGH CORE TO LOAD MODULE
NAME IS UNDEFINED - IBMBCSS ← Computer indicates that user has forgotten to reset core to high value.

12.47.06 >set core 384
CSS.300 06/15/76

12.47.27 >MONITOLD ← Try again.
ENTER NAME OF DISTRICT PLAN TO BE MODIFIED (I.E., THE NAME
OF A DISTRICT PLAN PREVIOUSLY CREATED USING THE MONITNEW OR
MONITOLD COMMAND)>ex4a
ENTER NAME OF REGION FILE (I.E., THE NAME OF THE FILE THAT
CONTAINS GEOGRAPHIC AND CALL VOLUME DATA FOR EACH REPORTING
AREA IN THE REGION OF INTEREST)>lawcity
ENTER NAME TO BE GIVEN TO THE NEW DISTRICT PLAN BEING CREATED>ex4b
EXECUTION:

NSF/RANN INTERACTIVE HYPERCUBE SYSTEM

MONITOR HERE. WHEN IN DOUBT, TYPE '?'.

THE INTERACTIVE MONITOR USES SPECIFIC TERMS TO REFER TO
RESPONSE UNITS, CALLS FOR SERVICE, ETC. WHICH MAY BE
DIFFERENT FROM THOSE YOU ARE ACCUSTOMED TO. WHILE THIS
TERMINOLOGY CANNOT BE MODIFIED WITHIN THE MONITOR ITSELF,
IT IS POSSIBLE TO PROVIDE YOUR OWN TERMS TO BE USED IN THE
FINAL HYPERCUBE OUTPUT BY USING THE "GLOSSARY" COMMAND
AFTER FIRST CREATING YOUR DISTRICT PLAN. DO YOU WANT AN
EXPLANATION OF THE TERMINOLOGY BEING USED BY THE MONITOR?:
>n

```
ENTER COMMAND:
>TITLE
$
TITLE OF PLAN:  'EXERCISE 4 - BALANCE TRAV TIME FOR EX3, 1ST TRY    '
CHANGE?:
>Y

ENTER TITLE OF DISTRICT PLAN:
>EXERCISE 4 - BALANCE TRAV TIME FOR EX3, 2ND TRY
TITLE ENTERED:
'EXERCISE 4 - BALANCE TRAV TIME FOR EX3, 2ND TRY    '


ENTER COMMAND:
>CONFIG

DO YOU WANT THE DISTRICT CONFIGURATION PRINTED OUT?:
>N

DO YOU WANT TO MODIFY THE DISTRICT CONFIGURATION?:
>Y
```

> Reference to output of p. 27 shows average travel time still greatest in beat 3 and lowest in beat 2. Map suggests moving 141 from 3 to 2 (see next page).

```
OPTION:
>6

ENTER NUMBER OF DISTRICT
 FROM WHICH YOU ARE SUBTRACTING:
>3

ENTER NUMBER OF DISTRICT
 TO WHICH YOU ARE ADDING:
>2
TYPE LIST OF REPORTING AREAS TO BE MOVED FROM DISTRICT
     3 TO DISTRICT      2:
>141


MORE CHANGES?:
>N

ALL REPORTING AREAS APPEAR IN AT LEAST ONE DISTRICT.

NO REPORTING AREAS APPEAR IN MORE THAN ONE DISTRICT.


ENTER COMMAND:
>SAVE

DO YOU WANT TO COMPUTE THE OUTPUT MEASURES AT
THIS TIME?>Y
ALL OUTPUT REQUESTED IN EX4B CAN BE PRINTED AT YOUR TERMINAL
AS IT IS GENERATED BY THE HYPERCUBE PROGRAM, OR IT CAN BE
STORED FOR LATER RETRIEVAL. DO YOU WANT THE OUTPUT STORED?>N
EXECUTION:
$
```

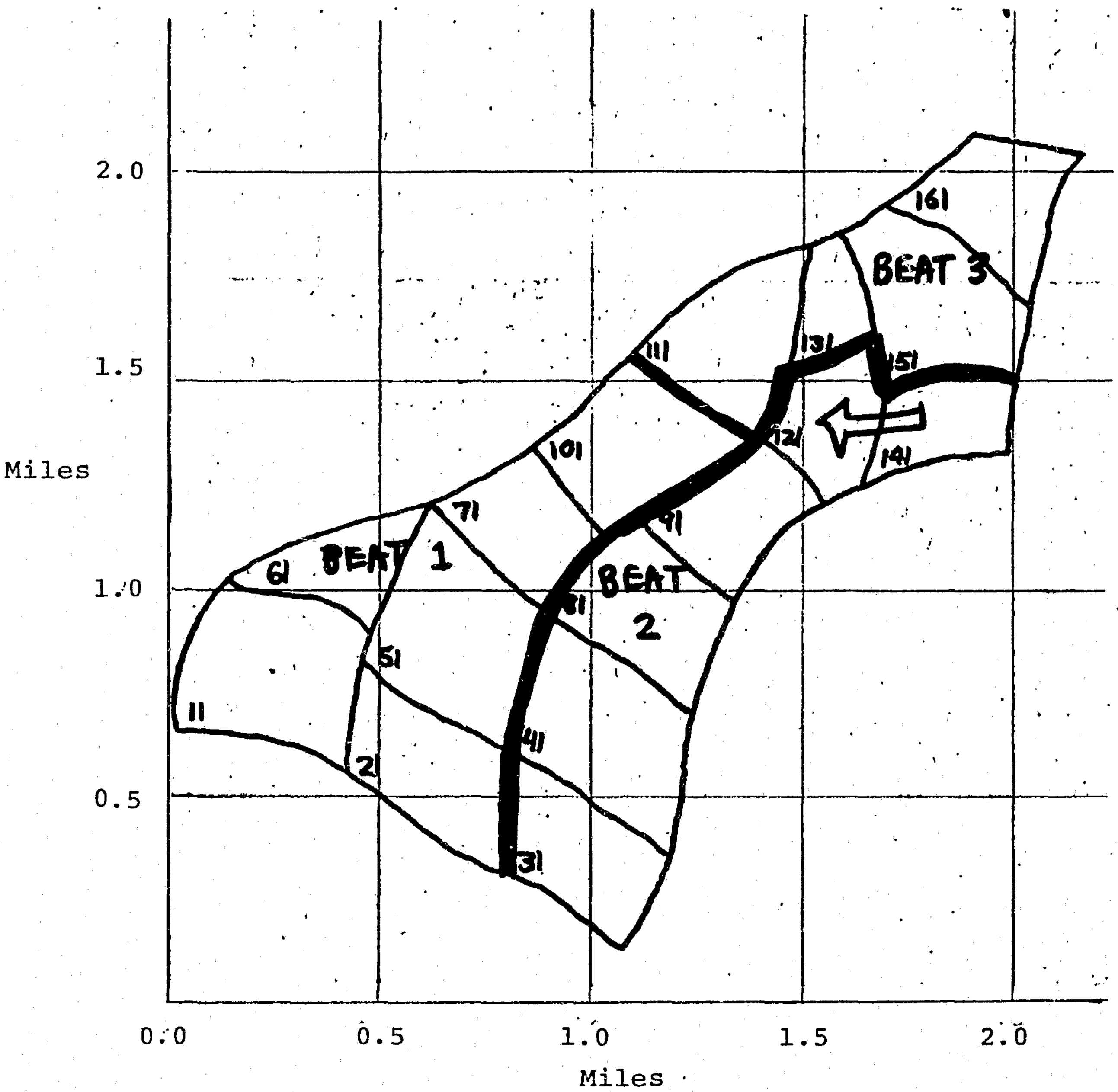


Figure C-5

MAP OF SAMPLE JURISDICTION

MODIFIED CENTER-OF-MASS DISPATCHING

FIRST PREFERENCE ASSIGNED TO BEAT CAR
ASSOCIATED WITH EACH BEAT
PROBLEM TITLE: EXERCISE 4 - BALANCE TRAV TIME FOR EX3, 2ND TRY

* ITERATIVE APPROXIMATION METHOD USED *
NUMBER OF ITERATIONS REQUIRED: 4
UNLIMITED CAPACITY QUEUE WITH 1_ST-COME 1_ST-SERVED QUEUE DISCIPLINE
RUN NUMBER: 1
BEAT CAR ...TOTAL NUMBER OF = 3
RPT AREA ...TOTAL NUMBER OF = 16
AVERAGE SERVICE TIME= 30.00 MINUTES
AVERAGE NUMBER PER HOUR OF CALLS FOR SERVICE = 3.000
AVERAGE NUMBER PER 30.00 MINUTES OF CALLS FOR SERVICE = 1.500
SPEED OF PATROL= 7.50 MPH
AVERAGE UTILIZATION FACTOR
(IN THE CASE OF UNLIMITED LINE CAPACITY)= 0.500

REGION-WIDE AVERAGE TRAVEL TIME= 3.486 MINUTES

AVERAGE TRAVEL TIME FOR QUEUED CALLS= 4.111 MINUTES
PROBABILITY OF SATURATION= 0.23684
REGION-WIDE AVERAGE WORKLOAD (% TIME BUSY)= 0.50000
STANDARD DEVIATION OF WORKLOAD= 0.063
MAXIMUM WORKLOAD IMBALANCE= 0.12368

FRACTION OF DISPATCHES THAT ARE INTER-BEAT = 0.44238

REGION-WIDE AVERAGE PATROL FREQUENCY= 0.228 PASSES PER HOUR

PERFORMANCE MEASURES THAT ARE SPECIFIC TO EACH BEAT CAR

ID OF BEAT CAR NAME	NO	WORKLOAD OF UNIT	% OF MEAN	FRACTION OF DISPATCHES OUT OF BEAT	% OF MEAN	AVERAGE TRAVEL TIME
BEAT CAR	1	0.554	110.7	.2237	50.6	2.975
BEAT CAR	2	0.516	103.3	.5672	128.2	3.601
BEAT CAR	3	0.430	86.0	.5794	131.0	4.032

PERFORMANCE MEASURES THAT ARE SPECIFIC TO EACH BEAT

Note further improvement in travel time balance

ID OF BEAT NAME	NO	WORKLOAD OF BEAT	% OF MEAN	FRACTION OF DISPATCHES INTER-BEAT	% OF MEAN	AVERAGE TRAVEL TIME
BEAT	1	0.829	165.7	.4744	107.2	3.527
BEAT	2	0.400	80.0	.4372	98.8	3.404
BEAT	3	0.271	54.3	.3515	79.5	3.490

ALL DONE

```
CORE RESET TO 256
CSS.300 06/15/76

12.54.38 >SET CORE 384
CSS.300 06/15/76

12.55.28 >MONITOLD
ENTER NAME OF DISTRICT PLAN TO BE MODIFIED (I.E., THE NAME
OF A DISTRICT PLAN PREVIOUSLY CREATED USING THE MONITNEW OR
MONITOLD COMMAND)>EX4B
ENTER NAME OF REGION FILE (I.E., THE NAME OF THE FILE THAT
CONTAINS GEOGRAPHIC AND CALL VOLUME DATA FOR EACH REPORTING
AREA IN THE REGION OF INTEREST)>LAWCITY
ENTER NAME TO BE GIVEN TO THE NEW DISTRICT PLAN BEING CREATED>EX4C
EXECUTION:
```

Now modify the district plan to better balance the car workloads.

```
NSF/RANN INTERACTIVE HYPERCUBE SYSTEM

MONITOR HERE.  WHEN IN DOUBT, TYPE '?' .

THE INTERACTIVE MONITOR USES SPECIFIC TERMS TO REFER TO
RESPONSE UNITS, CALLS FOR SERVICE, ETC. WHICH MAY BE
DIFFERENT FROM THOSE YOU ARE ACCUSTOMED TO.  WHILE THIS
TERMINOLOGY CANNOT BE MODIFIED WITHIN THE MONITOR ITSELF,
IT IS POSSIBLE TO PROVIDE YOUR OWN TERMS TO BE USED IN THE
FINAL HYPERCUBE OUTPUT BY USING THE "GLOSSARY" COMMAND
AFTER FIRST CREATING YOUR DISTRICT PLAN.  DO YOU WANT AN
EXPLANATION OF THE TERMINOLOGY BEING USED BY THE MONITOR?:
>N


ENTER COMMAND:
>TITLE

TITLE OF PLAN:  'EXERCISE 4 - BALANCE TRAV TIME FOR EX3, 2ND TRY        '
CHANGE?:
>Y

ENTER TITLE OF DISTRICT PLAN:
>EXERCISE 4 - NOW BAL CAR WORKLOADS SHOWN FOR EX4B
TITLE ENTERED:
'EXERCISE 4 - NOW BAL CAR WORKLOADS SHOWN FOR EX4B '
```

Reference to output of p. 200 shows car 1 has highest workload, car 3 had lowest workload.

```
ENTER COMMAND:
>CONFIG

DO YOU WANT THE DISTRICT CONFIGURATION PRINTED OUT?:
>N

DO YOU WANT TO MODIFY THE DISTRICT CONFIGURATION?:
>Y
```

```
OPTION:
>6 <---- Map (see next page) suggests moving 101 from 1 to 3.

ENTER NUMBER OF DISTRICT
 FROM WHICH YOU APE SUBTRACTING:
>1

ENTER NUMBER OF DISTRICT
 TO WHICH YOU ARE ADDING:
>3
TYPE LIST OF REPORTING AREAS TO BE MOVED FROM DISTRICT
     1 TO DISTRICT       3:
>101

MORE CHANGES?:
>N

ALL REPORTING AREAS APPEAR IN AT LEAST ONE DISTRICT.

NO REPORTING AREAS APPEAR IN MORE THAN ONE DISTRICT.


ENTER COMMAND:
>SAVE

DO YOU WANT TO COMPUTE THE OUTPUT MEASURES AT
THIS TIME?>Y
ALL OUTPUT REQUESTED IN EX4C CAN BE PRINTED AT YOUR TERMINAL
AS IT IS GENERATED BY THE HYPERCUBE PROGRAM, OR IT CAN BE
STORED FOR LATER RETRIEVAL. DO YOU WANT THE OUTPUT STORED?>N
EXECUTION:
$


 MODIFIED CENTER-OF-MASS DISPATCHING

 FIRST PREFERENCE ASSIGNED TO BEAT CAR
    ASSOCIATED WITH EACH BEAT
 PROBLEM TITLE: EXERCISE 4 - NOW BAL CAR WORKLOADS SHOWN FOR EX4B

     * ITERATIVE APPROXIMATION METHOD USED *
     NUMBER OF ITERATIONS REQUIRED:          3
 UNLIMITED CAPACITY QUEUE WITH 1_ST-COME 1_ST-SERVED QUEUE DISCIPLINE
 RUN NUMBER:  1
 BEAT CAR              ...TOTAL NUMBER OF =  3
 RPT AREA  ...TOTAL NUMBER OF =  16
 AVERAGE SERVICE TIME=  30.00 MINUTES
 AVERAGE NUMBER PER HOUR OF CALLS FOR SERVICE  =   3.000
 AVERAGE NUMBER PER  30.00 MINUTES OF CALLS FOR SERVICE  =   1.500
 SPEED OF PATROL=   7.50 MPH
 AVERAGE UTILIZATION FACTOR
    (IN THE CASE OF UNLIMITED LINE CAPACITY)=  0.500

 REGION-WIDE AVERAGE TRAVEL TIME=   3.398 MINUTES
```

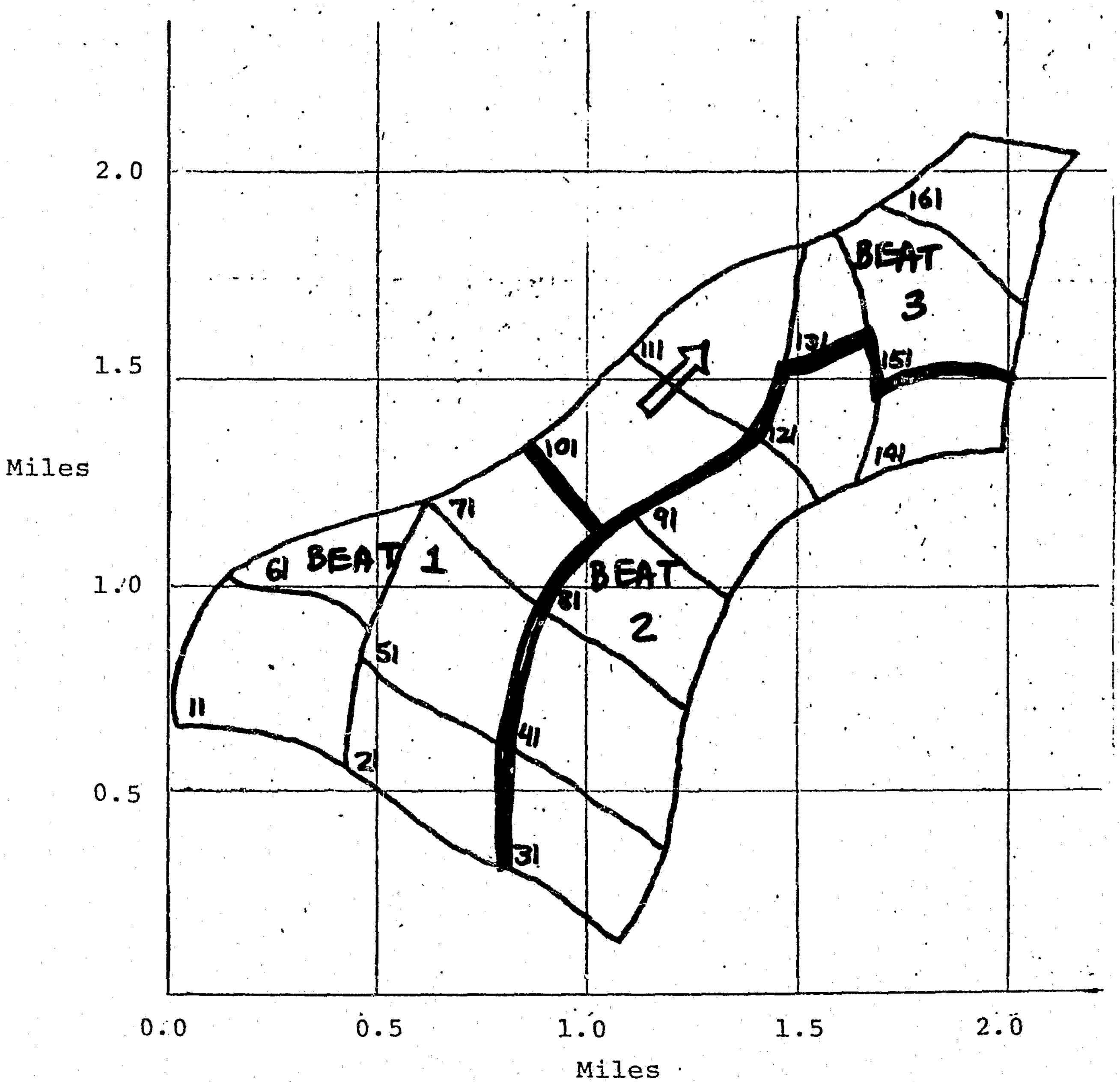


Figure C-6

MAP OF SAMPLE JURISDICTION

AVERAGE TRAVEL TIME FOR QUEUED CALLS= 4.111 MINUTES
PROBABILITY OF SATURATION= 0.23684
REGION-WIDE AVERAGE WORKLOAD (% TIME BUSY)= 0.50000
STANDARD DEVIATION OF WORKLOAD= 0.049
MAXIMUM WORKLOAD IMBALANCE= 0.09440

FRACTION OF DISPATCHES THAT ARE INTER-BEAT = 0.43275

REGION-WIDE AVERAGE PATROL FREQUENCY= 0.225 PASSES PER HOUR

Note improvement in workload balance for cars.

PERFORMANCE MEASURES THAT ARE SPECIFIC TO EACH BEAT CAR

ID OF BEAT CAR NAME	NO	WORKLOAD OF UNIT	% OF MEAN	FRACTION OF DISPATCHES OUT OF BEAT	% OF MEAN	AVERAGE TRAVEL TIME
BEAT CAR	1	0.541	108.1	.2535	58.6	2.825
BEAT CAR	2	0.513	102.7	.5617	129.8	3.613
BEAT CAR	3	0.446	89.2	.5039	116.4	3.863

Note slight degredation in travel time balance for beats.

PERFORMANCE MEASURES THAT ARE SPECIFIC TO EACH BEAT

ID OF BEAT NAME	NO	WORKLOAD OF BEAT	% OF MEAN	FRACTION OF DISPATCHES INTER-BEAT	% OF MEAN	AVERAGE TRAVEL TIME
BEAT	1	0.757	151.4	.4612	106.6	3.304
BEAT	2	0.400	80.0	.4341	100.3	3.334
BEAT	3	0.343	68.6	.3676	84.9	3.684

ALL DONE

CORE RESET TO 256
CSS.300 06/15/76

Exercise 5. OVERLAPPING BEATS

Beginning with the final district plan produced for exercise 4, determine the performance improvements to be obtained if two additional cars are available to provide additional coverage. Assign car 4 to overlay the beat whose car is experiencing the greatest workload (i.e., there will now be two cars covering this beat), and car 5 to overlay the two remaining beats (i.e., this car will patrol both beats). Set up dispatching preferences which will cause car 4 to receive about half the calls in its beat, and car 5 to be the second choice for dispatch to calls in the two beats it covers (i.e., second to the beat car, which will be first choice). Hint: you will have to use two runs of the hypercube program for this, one to determine the dispatch cost matrix for the five-car operation, and one based on a properly adjusted dispatch cost matrix.

```
13.02.49 >SET CORE 384
CSS.300 06/15/76
```

Modify the district plan of EX4C by adding two overlay cars.

```
13.03.39 >MONITOLD
ENTER NAME OF DISTRICT PLAN TO BE MODIFIED (I.E., THE NAME
OF A DISTRICT PLAN PREVIOUSLY CREATED USING THE MONITNEW OR
MONITOLD COMMAND)>EX4C
ENTER NAME OF REGION FILE (I.E., THE NAME OF THE FILE THAT
CONTAINS GEOGRAPHIC AND CALL VOLUME DATA FOR EACH REPORTING
AREA IN THE REGION OF INTEREST)>LAWCITY
ENTER NAME TO BE GIVEN TO THE NEW DISTRICT PLAN BEING CREATED>EX5A
EXECUTION:
```

Since car 1 has the highest average workload, car 4 will be assigned to beat 1. Therefore car 5 will be assigned to aid in covering beats 2 and 3.

```
NSF/RANN INTERACTIVE HYPERCUBE SYSTEM

MONITOR HERE.  WHEN IN DOUBT, TYPE '?' .

THE INTERACTIVE MONITOR USES SPECIFIC TERMS TO REFER TO
RESPONSE UNITS, CALLS FOR SERVICE, ETC. WHICH MAY BE
DIFFERENT FROM THOSE YOU ARE ACCUSTOMED TO.  WHILE THIS
TERMINOLOGY CANNOT BE MODIFIED WITHIN THE MONITOR ITSELF,
IT IS POSSIBLE TO PROVIDE YOUR OWN TERMS TO BE USED IN THE
FINAL HYPERCUBE OUTPUT BY USING THE "GLOSSARY" COMMAND
AFTER FIRST CREATING YOUR DISTRICT PLAN.  DO YOU WANT AN
EXPLANATION OF THE TERMINOLOGY BEING USED BY THE MONITOR?:
>N


ENTER COMMAND:
>TITLE

TITLE OF PLAN:  'EXERCISE 4 - NOW BAL CAR WORKLOADS SHOWN FOR EX4B '
CHANGE?:
>Y

ENTER TITLE OF DISTRICT PLAN:
>EXERCISE 5 - CAR 4 AIDS 1, CAR 5 AIDS 2,3 - STEP 1
TITLE ENTERED:
'EXERCISE 5 - CAR 4 AIDS 1, CAR 5 AIDS 2,3 - STEP 1'


ENTER COMMAND:
>CONFIG

DO YOU WANT THE DISTRICT CONFIGURATION PRINTED OUT?:
>N

DO YOU WANT TO MODIFY THE DISTRICT CONFIGURATION?:
>Y
```

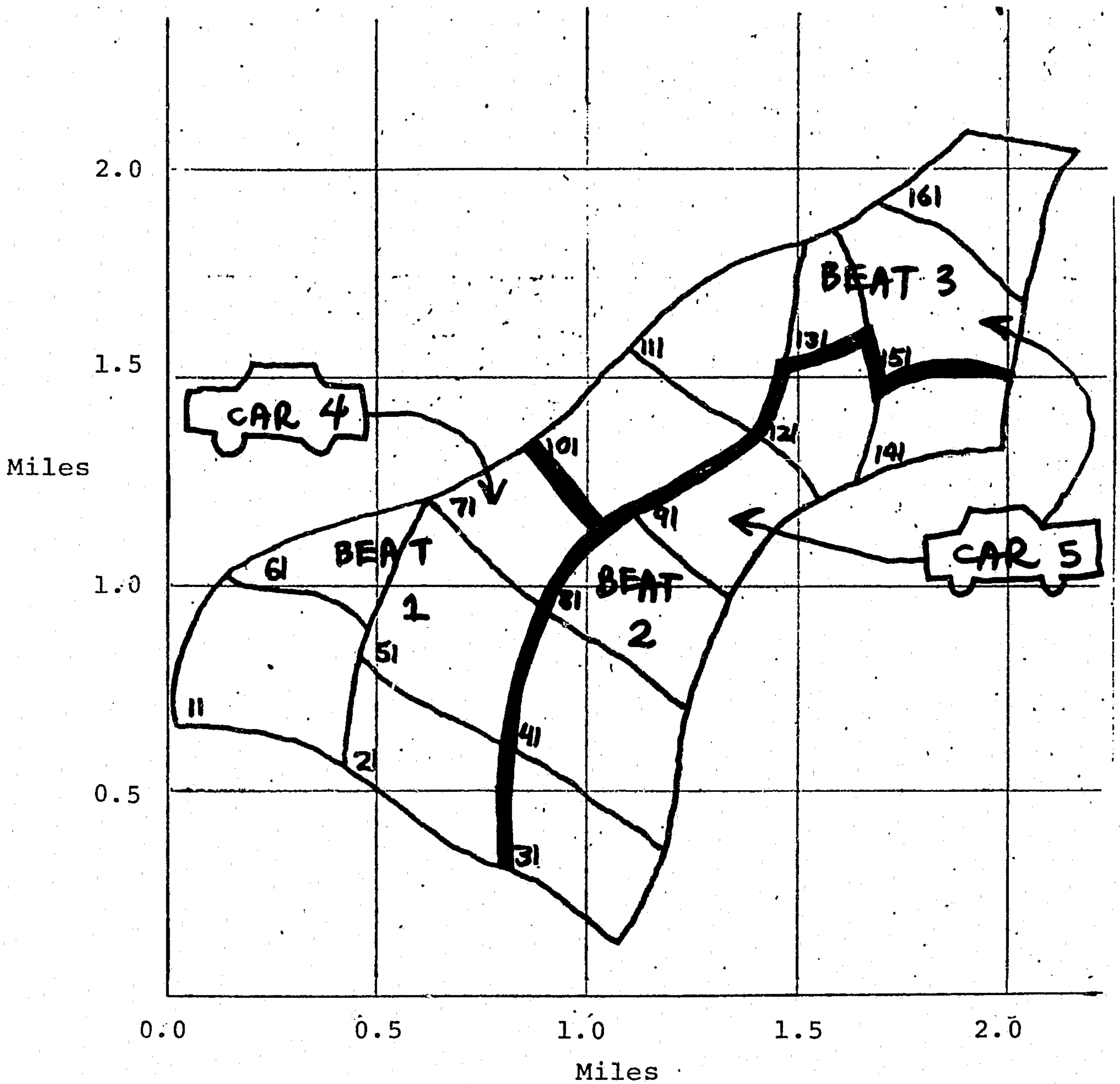


Figure C-7

MAP OF SAMPLE JURISDICTION

```
OPTION:
>?
THE FOLLOWING OPTIONS ARE AVAILABLE:
   1) ADD A NEW UNIT
   2) REMOVE A UNIT
   3) NOT IMPLEMENTED IN CURRENT VERSION
   4) ADD ONE OR MORE REPORTING AREAS TO A DISTRICT
   5) SUBTRACT ONE OR MORE REPORTING AREAS FROM A DISTRICT
   6) MOVE ONE OR MORE REPORTING AREAS FROM ONE DISTRICT TO
      ANOTHER
   7) COMBINE TWO DISTRICTS
   8) NOT IMPLEMENTED IN CURRENT VERSION
   9) PRINT THE DISTRICT CONFIGURATION
TYPE THE NUMBER OF THE OPTION (1 -  9) THAT YOU WISH
   TO USE:
>1

UNIT NUMBER:
>4

PPFS?:
>N

PPFS WILL BE PROPORTIONAL TO DEMAND FOR SERVICE.
REPORTING AREAS:
>OVERLAY 1
```

Note how simply the overlay assignment is indicated, without having to specify the reporting areas contained in beat 1.

```
MORE CHANGES?:
>Y

OPTION:
>1

UNIT NUMBER:
>5

PPFS?:
>N

PPFS WILL BE PROPORTIONAL TO DEMAND FOR SERVICE.
REPORTING AREAS:
>OVERLAY 2,3

MORE CHANGES?:
>N

ALL REPORTING AREAS APPEAR IN AT LEAST ONE DISTRICT.
```

```
THIS RUN HAS OVERLAPPING DISTRICTS.
DO YOU WANT A TABLE PRINTED SHOWING WHICH REPORTING
AREAS APPEAR IN MORE THAN ONE DISTRICT?:
>YES

REPORTING AREA      DISTRICTS

      11               1     4
      21               1     4
      31               2     5
      41               2     5
      51               1     4
      61               1     4
      71               1     4
      81               2     5
      91               2     5
     101               3     5
     111               3     5
     121               2     5
     131               3     5
     141               2     5
     151               3     5
     161               3     5
```

```
ENTER COMMAND:
>PRNT_COST
```

The travel cost matrix will be needed to check and set the dispatch policies specified for exercise 5.

```
COST MATRIX WILL BE PRINTED.
```

A preliminary set of output statistics must now be produced to generate the travel cost matrix.

```
ENTER COMMAND:
>SAVE

DO YOU WANT TO COMPUTE THE OUTPUT MEASURES AT
THIS TIME?>Y
ALL OUTPUT REQUESTED IN EX5A CAN BE PRINTED AT YOUR TERMINAL
AS IT IS GENERATED BY THE HYPERCUBE PROGRAM, OR IT CAN BE
STORED FOR LATER RETRIEVAL. DO YOU WANT THE OUTPUT STORED?>N
EXECUTION:



MODIFIED CENTER-OF-MASS DISPATCHING

FIRST PREFERENCE ASSIGNED TO BEAT CAR
   ASSOCIATED WITH EACH BEAT
```

ESTIMATED "COST" OF DISPATCHING I_TH BEAT CAR
TO J_TH RPT AREA

RPT AREA ID NO	BEAT CAR 1	BEAT CAR 2	BEAT CAR 3	BEAT CAR 4	BEAT CAR 5
11	0.00	3.77	8.42	1.37	5.91
21	0.00	3.17	7.82	1.52	5.31
31	3.68	0.00	7.18	3.68	4.67
41	2.72	0.00	5.82	2.72	3.31
51	0.00	2.20	6.26	0.79	3.75
61	0.00	3.80	6.74	1.16	4.23
71	0.00	2.56	4.62	2.43	2.11
81	2.83	0.00	4.22	2.83	1.71
91	4.51	0.00	2.54	4.51	0.30
101	4.23	2.36	0.00	4.23	1.26
111	6.11	3.71	0.00	6.11	1.57
121	6.39	0.00	1.71	6.39	1.85
131	7.47	5.07	0.00	7.47	2.93
141	7.43	0.00	2.67	7.43	2.89
151	8.55	6.15	0.00	8.55	4.01
161	7.95	5.55	0.00	7.95	3.41

PROBLEM TITLE: EXERCISE 5 - CAR 4 AIDS 1, CAR 5 AIDS 2,3 - STEP 1

* ITERATIVE APPROXIMATION METHOD USED *
NUMBER OF ITERATIONS REQUIRED: 5
UNLIMITED CAPACITY QUEUE WITH 1_ST-COME 1_ST-SERVED QUEUE DISCIPLINE
RUN NUMBER: 1
BEAT CAR ...TOTAL NUMBER OF = 5
RPT AREA ...TOTAL NUMBER OF = 16
AVERAGE SERVICE TIME= 30.00 MINUTES
AVERAGE NUMBER PER HOUR OF CALLS FOR SERVICE = 3.000
AVERAGE NUMBER PER 30.00 MINUTES OF CALLS FOR SERVICE = 1.500
SPEED OF PATROL= 7.50 MPH
AVERAGE UTILIZATION FACTOR
(IN THE CASE OF UNLIMITED LINE CAPACITY)= 0.300

REGION-WIDE AVERAGE TRAVEL TIME= 2.632 MINUTES

AVERAGE TRAVEL TIME FOR QUEUED CALLS= 4.111 MINUTES
PROBABILITY OF SATURATION= 0.02014
REGION-WIDE AVERAGE WORKLOAD (% TIME BUSY)= 0.30000
STANDARD DEVIATION OF WORKLOAD= 0.101
MAXIMUM WORKLOAD IMBALANCE= 0.26988

FRACTION OF DISPATCHES THAT ARE INTER-BEAT = 0.15906

REGION-WIDE AVERAGE PATROL FREQUENCY= 0.541 PASSES PER HOUR

PERFORMANCE MEASURES THAT ARE SPECIFIC TO EACH BEAT CAR

NAME	ID OF BEAT CAR NO	WORKLOAD OF UNIT	% OF MEAN	FRACTION OF DISPATCHES OUT OF BEAT	% OF MEAN	AVERAGE TRAVEL TIME
BEAT CAR	1	0.453	151.0	.0843	53.0	2.180
BEAT CAR	2	0.334	111.3	.1959	123.2	3.016
BEAT CAR	3	0.279	92.9	.1025	64.5	2.428
BEAT CAR	4	0.252	83.9	.1548	97.3	2.252
BEAT CAR	5	0.183	61.0	.3620	227.6	3.893

PERFORMANCE MEASURES THAT ARE SPECIFIC TO EACH BEAT

NAME	ID OF BEAT NO	WORKLOAD OF BEAT	% OF MEAN	FRACTION OF DISPATCHES INTER-BEAT	% OF MEAN	AVERAGE TRAVEL TIME
BEAT	1	0.757	252.4	.1711	107.5	2.417
BEAT	2	0.400	133.3	.2151	135.2	2.922
BEAT	3	0.343	114.3	.0640	40.2	2.781
BEAT	4	0.757	252.4	.1711	107.5	2.417
BEAT	5	0.743	247.6	.1454	91.4	2.857

ALL DONE

CORE RESET TO 256
CSS.300 06/15/76

13.18.09 >SET CORE 384
CSS.300 06/15/76

> The matrix on p. 210 car now be used to properly set the dispatch preferences.

13.19.34 >MONITOLD
ENTER NAME OF DISTRICT PLAN TO BE MODIFIED (I.E., THE NAME OF A DISTRICT PLAN PREVIOUSLY CREATED USING THE MONITNEW OR MONITOLD COMMAND)>EX5A
ENTER NAME OF REGION FILE (I.E., THE NAME OF THE FILE THAT CONTAINS GEOGRAPHIC AND CALL VOLUME DATA FOR EACH REPORTING AREA IN THE REGION OF INTEREST)>LAWCITY
ENTER NAME TO BE GIVEN TO THE NEW DISTRICT PLAN BEING CREATED>EX5B
EXECUTION:

> Car 4 will share work equally with car 1 in their beat if they both have the same travel cost for reporting areas in the beat. Since these costs are zero for car 1, they should be set to zero for car 4. This is done with FRONT command.

NSF/RANN INTERACTIVE HYPERCUBE SYSTEM

MONITOR HERE. WHEN IN DOUBT, TYPE '?' .

```
THE INTERACTIVE MONITOR USES SPECIFIC TERMS TO REFER TO
RESPONSE UNITS, CALLS FOR SERVICE, ETC. WHICH MAY BE
DIFFERENT FROM THOSE YOU ARE ACCUSTOMED TO.  WHILE THIS
TERMINOLOGY CANNOT BE MODIFIED WITHIN THE MONITOR ITSELF,
IT IS POSSIBLE TO PROVIDE YOUR OWN TERMS TO BE USED IN THE
FINAL HYPERCUBE OUTPUT BY USING THE "GLOSSARY" COMMAND
AFTER FIRST CREATING YOUR DISTRICT PLAN.  DO YOU WANT AN
EXPLANATION OF THE TERMINOLOGY BEING USED BY THE MONITOR?:
>N
$

ENTER COMMAND:
>TITLE

TITLE OF PLAN:  'EXERCISE 5 - CAR 4 AIDS 1, CAR 5 AIDS 2,3 - STEP 1'
CHANGE?:
>Y

ENTER TITLE OF DISTRICT PLAN:
>EXERCISE 5 - CAR 4 AIDS 1, CAR 5 AIDS 2,3 - STEP 2
TITLE ENTERED:
'EXERCISE 5 - CAR 4 AIDS 1, CAR 5 AIDS 2,3 - STEP 2'


ENTER COMMAND:
>FRONT

UNIT NUMBER:
>4

REPORTING AREAS:
>11,21,51,61,71  <------

ENTER COMMAND:
>MIDDLE  <------

UNIT NUMBER:
>5

COST:
>0.5

REPORTING AREAS:
>31,41,121,141


ENTER COMMAND:
>SAVE

DO YOU WANT TO COMPUTE THE OUTPUT MEASURES AT
THIS TIME?>Y
ALL OUTPUT REQUESTED IN EX5B CAN BE PRINTED AT YOUR TERMINAL
AS IT IS GENERATED BY THE HYPERCUBE PROGRAM, OR IT CAN BE
STORED FOR LATER RETRIEVAL. DO YOU WANT THE OUTPUT STORED?>N
EXECUTION:
$
```

> These are all the reporting areas in beat 1.

> For car 5 to be second for all calls arising in beats 2 and 3 its travel cost to reporting areas in these beats must be less than that of every car except the prime beat car. Reference to the matrix of p. 210 shows that car 5's travel costs for reporting areas 31, 41, 121, and 141 must be reduced. A small value, 0.5, is used for the revised travel cost.

MODIFIED CENTER-OF-MASS DISPATCHING

FIRST PREFERENCE ASSIGNED TO BEAT CAR
ASSOCIATED WITH EACH BEAT

This matrix shows that the desired dispatch policy has been correctly entered.

ESTIMATED "COST" OF DISPATCHING I_TH BEAT CAR
TO J_TH RPT AREA

RPT AREA ID NO	ID OF BEAT CAR: BEAT CAR 1	BEAT CAR 2	BEAT CAR 3	BEAT CAR 4	BEAT CAR 5
11	0.00	3.77	8.42	0.00	5.91
21	0.00	3.17	7.82	0.00	5.31
31	3.68	0.00	7.18	3.68	0.50
41	2.72	0.00	5.82	2.72	0.50
51	0.00	2.20	6.26	0.00	3.75
61	0.00	3.80	6.74	0.00	4.23
71	0.00	2.56	4.62	0.00	2.11
81	2.83	0.00	4.22	2.83	1.71
91	4.51	0.00	2.54	4.51	0.30
101	4.23	2.36	0.00	4.23	1.26
111	6.11	3.71	0.00	6.11	1.57
121	6.39	0.00	1.71	6.39	0.50
131	7.47	5.07	0.00	7.47	2.93
141	7.43	0.00	2.67	7.43	0.50
151	8.55	6.15	0.00	8.55	4.01
161	7.95	5.55	0.00	7.95	3.41

PROBLEM TITLE: EXERCISE 5 - CAR 4 AIDS 1, CAR 5 AIDS 2,3 - STEP 2

* ITERATIVE APPROXIMATION METHOD USED *
NUMBER OF ITERATIONS REQUIRED: 5
UNLIMITED CAPACITY QUEUE WITH 1_ST-COME 1_ST-SERVED QUEUE DISCIPLINE
RUN NUMBER: 1
BEAT CAR ...TOTAL NUMBER OF = 5
RPT AREA ...TOTAL NUMBER OF = 16
AVERAGE SERVICE TIME= 30.00 MINUTES
AVERAGE NUMBER PER HOUR OF CALLS FOR SERVICE = 3.000
AVERAGE NUMBER PER 30.00 MINUTES OF CALLS FOR SERVICE = 1.500
SPEED OF PATROL= 7.50 MPH
AVERAGE UTILIZATION FACTOR
(IN THE CASE OF UNLIMITED LINE CAPACITY)= 0.300

REGION-WIDE AVERAGE TRAVEL TIME= 2.650 MINUTES

AVERAGE TRAVEL TIME FOR QUEUED CALLS= 4.111 MINUTES
PROBABILITY OF SATURATION= 0.02014
REGION-WIDE AVERAGE WORKLOAD (% TIME BUSY)= 0.30000
STANDARD DEVIATION OF WORKLOAD= 0.062
MAXIMUM WORKLOAD IMBALANCE= 0.14122

FRACTION OF DISPATCHES THAT ARE INTER-BEAT = 0.10548

REGION-WIDE AVERAGE PATROL FREQUENCY= 0.543 PASSES PER HOUR

PERFORMANCE MEASURES THAT ARE SPECIFIC TO EACH BEAT CAR

NAME	ID OF BEAT CAR NO	WORKLOAD OF UNIT	% OF MEAN	FRACTION OF DISPATCHES OUT OF BEAT	% OF MEAN	AVERAGE TRAVEL TIME
BEAT CAR	1	0.345	115.0	.0491	46.5	2.157
BEAT CAR	2	0.335	111.6	.1993	188.9	3.022
BEAT CAR	3	0.272	90.5	.0737	69.9	2.441
BEAT CAR	4	0.345	115.0	.0491	46.5	2.157
BEAT CAR	5	0.204	67.9	.1817	172.2	3.993

PERFORMANCE MEASURES THAT ARE SPECIFIC TO EACH BEAT

NAME	ID OF BEAT NO	WORKLOAD OF BEAT	% OF MEAN	FRACTION OF DISPATCHES INTER-BEAT	% OF MEAN	AVERAGE TRAVEL TIME
BEAT	1	0.757	252.4	.1332	126.2	2.374
BEAT	2	0.400	133.3	.0835	79.2	3.067
BEAT	3	0.343	114.3	.0680	64.5	2.778
BEAT	4	0.757	252.4	.1332	126.2	2.374
BEAT	5	0.743	247.6	.0763	72.4	2.934

ALL DONE

CORE RESET TO 256
CSS.300 06/15/76

Exercise 6. TRAVEL TIME CALIBRATION, NON-CFS WORK, AND MULTIPLE CAR DISPATCHING

Using the final beat plan produced for exercise 5, modify the input data to account for the following observations derived from data produced in a newly completed study of field operations:

(1) Figures on travel times derived from a review of 500 dispatches for which these data were available indicate that the district-wide average travel time is 4.0 minutes.

(2) For a quarter of the calls for service two patrol cars are dispatched. On the average, the second cars dispatched are out of service for 20 minutes (including travel time); first cars dispatched are out of service for an average of 30 minutes. Because of the procedure used to compile data for the run of exercise 3, the time spent by second cars and the number of such dispatches had been overlooked.

(3) Each car is occupied with non-cfs work an average of two hours per watch. This includes meals, occasional foot patrol, processing warrants, trips to the garage, and other such non-dispatched activities. Here too, data on these activities had been previously overlooked.

Since use of the dispatch cost matrix is not required for any part of this analysis, cancel the printing of it, and produce the hypercube program output at your terminal.

```
13.31.48 >SET CORE 384
CSS.300 06/15/76

13.32.03 >MONITOLD
ENTER NAME OF DISTRICT PLAN TO BE MODIFIED (I.E., THE NAME
OF A DISTRICT PLAN PREVIOUSLY CREATED USING THE MONITNEW OR
MONITOLD COMMAND)>EX5B
ENTER NAME OF REGION FILE (I.E., THE NAME OF THE FILE THAT
CONTAINS GEOGRAPHIC AND CALL VOLUME DATA FOR EACH REPORTING
AREA IN THE REGION OF INTEREST)>LAWCITY
ENTER NAME TO BE GIVEN TO THE NEW DISTRICT PLAN BEING CREATED>EX6
EXECUTION:




NSF/RANN INTERACTIVE HYPERCUBE SYSTEM

MONITOR HERE.  WHEN IN DOUBT, TYPE '?' .

THE INTERACTIVE MONITOR USES SPECIFIC TERMS TO REFER TO
RESPONSE UNITS, CALLS FOR SERVICE, ETC. WHICH MAY BE
DIFFERENT FROM THOSE YOU ARE ACCUSTOMED TO.  WHILE THIS
TERMINOLOGY CANNOT BE MODIFIED WITHIN THE MONITOR ITSELF,
IT IS POSSIBLE TO PROVIDE YOUR OWN TERMS TO BE USED IN THE
FINAL HYPERCUBE OUTPUT BY USING THE "GLOSSARY" COMMAND
AFTER FIRST CREATING YOUR DISTRICT PLAN.  DO YOU WANT AN
EXPLANATION OF THE TERMINOLOGY BEING USED BY THE MONITOR?:
>N
$

ENTER COMMAND:
>TITLE

TITLE OF PLAN:  'EXERCISE 5 - CAR 4 AIDS 1, CAR 5 AIDS 2,3 - STEP 2'
CHANGE?:
>Y

ENTER TITLE OF DISTRICT PLAN:
>EXERCISE 6 - FIX TRAV TIME;MULT DISP;NON-CFS WORK
TITLE ENTERED:
'EXERCISE 6 - FIX TRAV TIME,MULT DISP,NON-CFS WORK '

ENTER COMMAND:
>SPEED
```

To correct the region-wide average travel time, shown on p. 213 (2.650 minutes), to a value of 4.0 the patrol speed must be changed to:

$$(15) \times (2.650/4.0) = 9.94$$

```
PATROL UNIT RESPONSE SPEED:  15.00
CHANGE?:
>Y

ENTER PATROL UNIT RESPONSE SPEED:
>9.945
PATROL UNIT RESPONSE SPEED ENTERED:   9.94
```

```
ENTER COMMAND:
>ADJUST
```

This command is used to account for multiple car dispatches and non-cfs work.

```
DO YOU WANT TO ADJUST THE AVERAGE NUMBER OF CALLS FOR
SERVICE PER HOUR TO ACCOUNT FOR MULTIPLE CAR DISPATCHES?:
>Y

ENTER THE AVERAGE SERVICE TIME, IN MINUTES, FOR THE  1-ST
DISPATCHED UNIT:
>30

ENTER FRACTION OF CALLS REQUIRING  2 OR MORE UNITS:
>0.25

ENTER THE AVERAGE SERVICE TIME, IN MINUTES, FOR THE  2-ND
DISPATCHED UNIT:
>20

ENTER FRACTION OF CALLS REQUIRING  3 OR MORE UNITS:
>0.0

DO YOU WANT TO ADJUST THE AVERAGE NUMBER OF CALLS FOR
SERVICE PER HOUR TO ACCOUNT FOR NON-CALL-FOR-SERVICE
WORKLOAD?:
>Y

ENTER THE AVERAGE NUMBER OF MINUTES PER HOUR A RESPONSE
UNIT SPENDS ON NON-CALL-FOR-SERVICE WORK:
>15

ADJUSTED NUMBER OF CALLS FOR SERVICE PER HOUR:  6.0

ENTER COMMAND:
>PRNT_COST
```

Cancel printing of the travel cost matrix since it is not needed for Exercise 6.

```
COST MATRIX WILL NOT BE PRINTED.

ENTER COMMAND:
>SAVE

DO YOU WANT TO COMPUTE THE OUTPUT MEASURES AT
THIS TIME?>Y
ALL OUTPUT REQUESTED IN EX6 CAN BE PRINTED AT YOUR TERMINAL
AS IT IS GENERATED BY THE HYPERCUBE PROGRAM, OR IT CAN BE
STORED FOR LATER RETRIEVAL. DO YOU WANT THE OUTPUT STORED?>N
EXECUTION:
$
```

MODIFIED CENTER-OF-MASS DISPATCHING

FIRST PREFERENCE ASSIGNED TO BEAT CAR
ASSOCIATED WITH EACH BEAT
PROBLEM TITLE: EXERCISE 6 - FIX TRAV TIME,MULT DISP,NON-CFS WORK

* ITERATIVE APPROXIMATION METHOD USED *
NUMBER OF ITERATIONS REQUIRED: 4
UNLIMITED CAPACITY QUEUE WITH 1_ST-COME 1_ST-SERVED QUEUE DISCIPLINE
RUN NUMBER: 1
BEAT CAR ...TOTAL NUMBER OF = 5
RPT AREA ...TOTAL NUMBER OF = 16
AVERAGE SERVICE TIME= 30.00 MINUTES
AVERAGE NUMBER PER HOUR OF CALLS FOR SERVICE = 6.000
AVERAGE NUMBER PER 30.00 MINUTES OF CALLS FOR SERVICE = 3.000
SPEED OF PATROL= 7.50 MPH
AVERAGE UTILIZATION FACTOR
(IN THE CASE OF UNLIMITED LINE CAPACITY)= 0.600

REGION-WIDE AVERAGE TRAVEL TIME= 4.976 MINUTES ← Note that this is not 4.0, as desired.

AVERAGE TRAVEL TIME FOR QUEUED CALLS= 6.204 MINUTES
PROBABILITY OF SATURATION= 0.23615
REGION-WIDE AVERAGE WORKLOAD (% TIME BUSY)= 0.60000
STANDARD DEVIATION OF WORKLOAD= 0.036
MAXIMUM WORKLOAD IMBALANCE= 0.06781

FRACTION OF DISPATCHES THAT ARE INTER-BEAT = 0.32469

REGION-WIDE AVERAGE PATROL FREQUENCY= 0.310 PASSES PER HOUR

PERFORMANCE MEASURES THAT ARE SPECIFIC TO EACH BEAT CAR

ID OF BEAT CAR NAME	NO	WORKLOAD OF UNIT	% OF MEAN	FRACTION OF DISPATCHES OUT OF BEAT	% OF MEAN	AVERAGE TRAVEL TIME
BEAT CAR	1	0.627	104.4	.2238	68.9	4.217
BEAT CAR	2	0.624	104.1	.4649	143.2	5.268
BEAT CAR	3	0.559	93.1	.3870	119.2	5.127
BEAT CAR	4	0.627	104.4	.2220	68.4	4.207
BEAT CAR	5	0.563	93.9	.3357	103.4	6.260

PERFORMANCE MEASURES THAT ARE SPECIFIC TO EACH BEAT

NAME	ID OF BEAT NO	WORKLOAD OF BEAT	% OF MEAN	FRACTION OF DISPATCHES INTER-BEAT	% OF MEAN	AVERAGE TRAVEL TIME
BEAT	1	1.514	252.4	.3477	107.1	4.562
BEAT	2	0.800	133.3	.3178	97.9	5.144
BEAT	3	0.686	114.3	.2812	86.6	5.699
BEAT	4	1.514	252.4	.3477	107.1	4.562
BEAT	5	1.486	247.6	.3009	92.7	5.400

ALL DONE

> The region-wide average travel time has come out wrong because the call rate increase has also affected travel time. Leaving the call rate fixed, revise the speed again.

CORE RESET TO 256
CSS.300 06/15/76

13.43.17 >SET CORE 384
CSS.300 06/15/76

13.43.47 >MONITOLD
ENTER NAME OF DISTRICT PLAN TO BE MODIFIED (I.E., THE NAME OF A DISTRICT PLAN PREVIOUSLY CREATED USING THE MONITNEW OR MONITOLD COMMAND)>EX6
ENTER NAME OF REGION FILE (I.E., THE NAME OF THE FILE THAT CONTAINS GEOGRAPHIC AND CALL VOLUME DATA FOR EACH REPORTING AREA IN THE REGION OF INTEREST)>LAWCITY
ENTER NAME TO BE GIVEN TO THE NEW DISTRICT PLAN BEING CREATED>EX6A
EXECUTION:

NSF/RANN INTERACTIVE HYPERCUBE SYSTEM

MONITOR HERE. WHEN IN DOUBT, TYPE '?' .

THE INTERACTIVE MONITOR USES SPECIFIC TERMS TO REFER TO RESPONSE UNITS, CALLS FOR SERVICE, ETC. WHICH MAY BE DIFFERENT FROM THOSE YOU ARE ACCUSTOMED TO. WHILE THIS TERMINOLOGY CANNOT BE MODIFIED WITHIN THE MONITOR ITSELF, IT IS POSSIBLE TO PROVIDE YOUR OWN TERMS TO BE USED IN THE FINAL HYPERCUBE OUTPUT BY USING THE "GLOSSARY" COMMAND AFTER FIRST CREATING YOUR DISTRICT PLAN. DO YOU WANT AN EXPLANATION OF THE TERMINOLOGY BEING USED BY THE MONITOR?:
>N
$

> The region-wide average travel time shown on p. 218 is 4.976 minutes. To correct it to 4.0 the speed must be changed to:
> $(9.94) \times (4.976/4.0) = 12.372$

ENTER COMMAND:
>SPEED

PATROL UNIT RESPONSE SPEED: 9.94
CHANGE?:
>Y

```
ENTER PATROL UNIT RESPONSE SPEED:
>12.372
PATROL UNIT RESPONSE SPEED ENTERED:  12.37


ENTER COMMAND:
>SUMMARY
```

This command allows a brief review of the highlights of the district plan.

```
      SUMMARY OF DISTRICT PLAN

NUMBER OF UNITS:          5
NUMBER OF REPORTING AREAS:        16
TITLE OF PLAN: EXERCISE 6 - FIX TRAV TIME,MULT DISP,NON-CFS WORK
PATROL UNIT RESPONSE SPEED:  12.37
NUMBER OF WORKLOAD LEVELS:        1
PATROL UNIT SERVICE TIME:   30.0
NUMBER OF CALLS FOR SERVICE PER HOUR:    6.0
DISPATCH POLICY:  MCM
DISTRICT CAR FIRST.
INFINITE CAPACITY QUEUE.
STATISTICS GENERATED:  ONLY APPROXIMATE STATISTICS
```

The following summarize the advanced commands specified.

```
'PRNT_VST'
'PATROL'         7.5
'CORTMC'      0.667
'FRONT'       4                5      11      21      51      61      71
'MIDDLE'      5    0.50        4      31      41     121     141


ENTER COMMAND:
>SAVE

DO YOU WANT TO COMPUTE THE OUTPUT MEASURES AT
THIS TIME?>Y
ALL OUTPUT REQUESTED IN EX6A CAN BE PRINTED AT YOUR TERMINAL
AS IT IS GENERATED BY THE HYPERCUBE PROGRAM, OR IT CAN BE
STORED FOR LATER RETRIEVAL. DO YOU WANT THE OUTPUT STORED?>N
EXECUTION:
$

MODIFIED CENTER-OF-MASS DISPATCHING

FIRST PREFERENCE ASSIGNED TO BEAT CAR
   ASSOCIATED WITH EACH BEAT
PROBLEM TITLE: EXERCISE 6 - FIX TRAV TIME,MULT DISP,NON-CFS WORK

    * ITERATIVE APPROXIMATION METHOD USED *
    NUMBER OF ITERATIONS REQUIRED:          4
UNLIMITED CAPACITY QUEUE WITH 1_ST-COME 1_ST-SERVED QUEUE DISCIPLINE
RUN NUMBER:  1
BEAT CAR              ...TOTAL NUMBER OF =  5
RPT AREA  ...TOTAL NUMBER OF =  16
AVERAGE SERVICE TIME=  30.00 MINUTES
AVERAGE NUMBER PER HOUR OF CALLS FOR SERVICE  =   6.000
AVERAGE NUMBER PER  30.00 MINUTES OF CALLS FOR SERVICE  =   3.000
SPEED OF PATROL=   7.50 MPH
```

AVERAGE UTILIZATION FACTOR
(IN THE CASE OF UNLIMITED LINE CAPACITY)= 0.600

Now the average travel time is correct, except for a small round-off error.

REGION-WIDE AVERAGE TRAVEL TIME= 3.998 MINUTES

AVERAGE TRAVEL TIME FOR QUEUED CALLS= 4.985 MINUTES
PROBABILITY OF SATURATION= 0.23615
REGION-WIDE AVERAGE WORKLOAD (% TIME BUSY)= 0.60000
STANDARD DEVIATION OF WORKLOAD= 0.036
MAXIMUM WORKLOAD IMBALANCE= 0.06781

FRACTION OF DISPATCHES THAT ARE INTER-BEAT = 0.32469

REGION-WIDE AVERAGE PATROL FREQUENCY= 0.310 PASSES PER HOUR

PERFORMANCE MEASURES THAT ARE SPECIFIC TO EACH BEAT CAR

ID OF BEAT CAR NAME	NO	WORKLOAD OF UNIT	% OF MEAN	FRACTION OF DISPATCHES OUT OF BEAT	% OF MEAN	AVERAGE TRAVEL TIME
BEAT CAR	1	0.627	104.4	.2238	68.9	3.388
BEAT CAR	2	0.624	104.1	.4649	143.2	4.233
BEAT CAR	3	0.559	93.1	.3870	119.2	4.120
BEAT CAR	4	0.627	104.4	.2220	68.4	3.381
BEAT CAR	5	0.563	93.9	.3357	103.4	5.031

PERFORMANCE MEASURES THAT ARE SPECIFIC TO EACH BEAT

ID OF BEAT NAME	NO	WORKLOAD OF BEAT	% OF MEAN	FRACTION OF DISPATCHES INTER-BEAT	% OF MEAN	AVERAGE TRAVEL TIME
BEAT	1	1.514	252.4	.3477	107.1	3.666
BEAT	2	0.800	133.3	.3178	97.9	4.133
BEAT	3	0.686	114.3	.2812	86.6	4.580
BEAT	4	1.514	252.4	.3477	107.1	3.666
BEAT	5	1.486	247.6	.3009	92.7	4.339

ALL DONE

CORE RESET TO 256
CSS.300 06/15/76

Exercise 7. BENEFITS OF AUTOMATIC VEHICLE LOCATION

Consider once again the district plan described in Exercise 3. Determine what improvements in performance would result if dispatchers were provided with automatic vehicle location equipment. (Hint: use the COMPARE command. Don't forget to use the district plan for Exercise 3, not Exercise 6.) Suppress unwanted output tables which had been requested for Exercise 3.

```
12.11.59 >SET CORE 384
CSS.300 06/15/76

12.12.13 >MINITOLD
INVALID CSS COMMAND

12.12.18 >MONITOLD
ENTER NAME OF DISTRICT PLAN TO BE MODIFIED (I.E., THE NAME
OF A DISTRICT PLAN PREVIOUSLY CREATED USING THE MONITNEW OR
MONITOLD COMMAND)>ex3
ENTER NAME OF REGION FILE (I.E., THE NAME OF THE FILE THAT
CONTAINS GEOGRAPHIC AND CALL VOLUME DATA FOR EACH REPORTING
AREA IN THE REGION OF INTEREST)>LAWCITY
ENTER NAME TO BE GIVEN TO THE NEW DISTRICT PLAN BEING CREATED>ex7
EXECUTION:




NSF/RANN INTERACTIVE HYPERCUBE SYSTEM

MONITOR HERE.  WHEN IN DOUBT, TYPE '?' .

THE INTERACTIVE MONITOR USES SPECIFIC TERMS TO REFER TO
RESPONSE UNITS, CALLS FOR SERVICE, ETC. WHICH MAY BE
DIFFERENT FROM THOSE YOU ARE ACCUSTOMED TO.  WHILE THIS
TERMINOLOGY CANNOT BE MODIFIED WITHIN THE MONITOR ITSELF,
IT IS POSSIBLE TO PROVIDE YOUR OWN TERMS TO BE USED IN THE
FINAL HYPERCUBE OUTPUT BY USING THE "GLOSSARY" COMMAND
AFTER FIRST CREATING YOUR DISTRICT PLAN.  DO YOU WANT AN
EXPLANATION OF THE TERMINOLOGY BEING USED BY THE MONITOR?:
>N
$

ENTER COMMAND:
>TITLE

TITLE OF PLAN:  'EXERCISE 3 - 3 CARS IN LAWCITY
CHANGE?:
>E[illegible]YES

ENTER TITLE OF DISTRICT PLAN:
>EXERCISE 7 - COMPARE SERVICE OF MCM WITH AVL FOR EX3
TITLE ENTERED:
'EXERCISE 7 - COMPARE SERVICE OF MCM WITH AVL FOR E'


ENTER COMMAND:
>TITLE

TITLE OF PLAN:  'EXERCISE 7 - COMPARE SERVICE OF MCM WITH AVL FOR E'
CHANGE?:
>Y
```

```
ENTER TITLE OF DISTRICT PLAN:
>EXERCISE 7 - COMPARE AVL WITH MCM FOR EX3
TITLE ENTERED:
'EXERCISE 7 - COMPARE AVL WITH MCM FOR EX3


ENTER COMMAND:
>COMPARE

COMPARE CARD WILL BE GENERATED.

*** WARNING ***
ONLY EXACT STATISTICS WILL BE GENERATED, SINCE
THE COMPARE FEATURE CANNOT BE USED WITH THE
HYPERCUBE APPROXIMATION.


ENTER COMMAND:
>NO_PRNT

ONLY REGION, UNIT, AND DISTRICT PERFORMANCE MEASURES
WILL BE PRINTED.


ENTER COMMAND:
>PRNT_TR


TRAVEL MATRIX WILL NOT BE PRINTED.


ENTER COMMAND:
>SAVE

DO YOU WANT TO COMPUTE THE OUTPUT MEASURES AT
THIS TIME?>Y
ENTER NAME OF REGION FILE (I.E., THE NAME OF THE FILE THAT
CONTAINS GEOGRAPHIC AND CALL VOLUME DATA FOR EACH REPORTING
AREA IN THE REGION OF INTEREST)>LAWCITY
ENTER NAME OF DISTRICT PLAN (I.E., THE NAME GIVEN TO THE DISTRICT
PLAN CREATED USING THE MONITNEW OR MONITOLD COMMAND)>EX7
ALL OUTPUT REQUESTED IN EX7 CAN BE PRINTED AT YOUR TERMINAL
AS IT IS GENERATED BY THE HYPERCUBE PROGRAM, OR IT CAN BE
STORED FOR LATER RETRIEVAL. DO YOU WANT THE OUTPUT STORED?>N
EXECUTION:
$
```

MODIFIED CENTER-OF-MASS DISPATCHING

FIRST PREFERENCE ASSIGNED TO BEAT CAR
ASSOCIATED WITH EACH BEAT
PROBLEM TITLE: EXERCISE 7 - COMPARE AVL WITH MCM FOR EX3
UNLIMITED CAPACITY QUEUE WITH 1_ST-COME 1_ST-SERVED QUEUE DISCIPLINE
RUN NUMBER: 1
BEAT CAR ...TOTAL NUMBER OF = 3
RPT AREA ...TOTAL NUMBER OF = 16
AVERAGE SERVICE TIME= 30.00 MINUTES
AVERAGE NUMBER PER HOUR OF CALLS FOR SERVICE = 3.000
AVERAGE NUMBER PER 30.00 MINUTES OF CALLS FOR SERVICE = 1.500
SPEED OF PATROL= 7.50 MPH
TOTAL PROBABILITY OF ERROR WITH MCM = 0.07356
AVERAGE UTILIZATION FACTOR
(IN THE CASE OF UNLIMITED LINE CAPACITY)= 0.500

REGION-WIDE AVERAGE TRAVEL TIME= 3.283 MINUTES

AVERAGE TRAVEL TIME FOR QUEUED CALLS= 4.111 MINUTES
PROBABILITY OF SATURATION= 0.23684
REGION-WIDE AVERAGE WORKLOAD (% TIME BUSY)= 0.50000
STANDARD DEVIATION OF WORKLOAD= 0.047
MAXIMUM WORKLOAD IMBALANCE= 0.08608

FRACTION OF DISPATCHES THAT ARE INTER-BEAT = 0.49558

REGION-WIDE AVERAGE PATROL FREQUENCY= 0.224 PASSES PER HOUR

PERFORMANCE MEASURES THAT ARE SPECIFIC TO EACH BEAT CAR

ID OF BEAT CAR NAME	NO	WORKLOAD OF UNIT	% OF MEAN	FRACTION OF DISPATCHES OUT OF BEAT	% OF MEAN	AVERAGE TRAVEL TIME
BEAT CAR	1	0.532	106.3	.2846	57.4	2.882
BEAT CAR	2	0.523	104.5	.6702	135.2	3.135
BEAT CAR	3	0.446	89.1	.5426	109.5	3.935

PERFORMANCE MEASURES THAT ARE SPECIFIC TO EACH BEAT

ID OF BEAT NAME	NO	WORKLOAD OF BEAT	% OF MEAN	FRACTION OF DISPATCHES INTER-BEAT	% OF MEAN	AVERAGE TRAVEL TIME
BEAT	1	0.829	165.7	.5409	109.1	3.273
BEAT	2	0.343	68.6	.4972	100.3	2.929
BEAT	3	0.329	65.7	.3796	76.6	3.676

ALL DONE

CORE RESET TO 256
CSS.300 06/15/76

Exercise 8. VARIABLE SERVICE TIMES

Returning again to the district plan described in Exercise 3, determine the impact of fielding a two-man car in beat 1 (i.e., the beat from which the majority of the calls for service are originating). Assume that the average service time for the two-man car is 20 minutes per incident, and that no other features of the district plan need be changed. (Hint: use the VST command. Don't forget to use the district plan for Exercise 3, not Exercise 7.) Suppress unwanted output tables which had been requested for Exercise 3.

```
12.21.48 >SET CORE 384
C3S.300 06/15/76

12.22.04 >MONITOLD
ENTER NAME OF DISTRICT PLAN TO BE MODIFIED (I.E., THE NAME
OF A DISTRICT PLAN PREVIOUSLY CREATED USING THE MONITNEW OR
MONITOLD COMMAND)>EX3
ENTER NAME OF REGION FILE (I.E., THE NAME OF THE FILE THAT
CONTAINS GEOGRAPHIC AND CALL VOLUME DATA FOR EACH REPORTING
AREA IN THE REGION OF INTEREST)>LAWCITY
ENTER NAME TO BE GIVEN TO THE NEW DISTRICT PLAN BEING CREATED>EX8
EXECUTION:




NSF/RANN INTERACTIVE HYPERCUBE SYSTEM

MONITOR HERE.  WHEN IN DOUBT, TYPE '?' .

THE INTERACTIVE MONITOR USES SPECIFIC TERMS TO REFER TO
RESPONSE UNITS, CALLS FOR SERVICE, ETC. WHICH MAY BE
DIFFERENT FROM THOSE YOU ARE ACCUSTOMED TO.  WHILE THIS
TERMINOLOGY CANNOT BE MODIFIED WITHIN THE MONITOR ITSELF,
IT IS POSSIBLE TO PROVIDE YOUR OWN TERMS TO BE USED IN THE
FINAL HYPERCUBE OUTPUT BY USING THE "GLOSSARY" COMMAND
AFTER FIRST CREATING YOUR DISTRICT PLAN.  DO YOU WANT AN
EXPLANATION OF THE TERMINOLOGY BEING USED BY THE MONITOR?:
>N
$

ENTER COMMAND:
>TITLE

TITLE OF PLAN:  'EXERCISE 3 - 3 CARS IN LAWCITY
CHANGE?:
>Y

ENTER TITLE OF DISTRICT PLAN:
>EXERCISE 8 - ADD 2ND MAN TO EX3 CAR 1
TITLE ENTERED:
'EXERCISE 8 - ADD 2ND MAN TO EX3 CAR 1


ENTER COMMAND:
>VST

OPTION:
>?

THE FOLLOWING TWO OPTIONS ARE AVAILABLE:
   1) PRINT THE CURRENT VARIABLE SERVICE TIMES (IF ANY).
   2) ENTER NEW VARIABLE SERVICE TIMES.

TYPE THE NUMBER OF THE OPTION THAT YOU WANT:
>1
```

```
NO VARIABLE SERVICE TIMES


ENTER COMMAND:
>2

UNKNOWN COMMAND:  2

ENTER COMMAND:
>VST

OPTION:
>2

ENTER SERVICE TIMES:
>?

SEE USER'S MANUAL, P. 71, FOR EXPLANATION OF SERVICE
TIMES THAT VARY BY RESPONSE UNIT.

ENTER SERVICE TIMES:
>1 20.0 2 30.0 3 30.0

*** ERROR ***
YOU TYPED MORE SERVICE TIMES THAN THERE ARE UNITS
TRY AGAIN

ENTER SERVICE TIMES:
>20.0 30.0 30.0

AVERAGE SERVICE TIME IS NOW  26.7




*** WARNING ***
ONLY EXACT STATISTICS WILL BE GENERATED, SINCE
VARIABLE SERVICE TIMES CANNOT BE USED WITH THE HYPERCUBE
APPROXIMATION.


ENTER COMMAND:
>NO_PRNT

ONLY REGION, UNIT, AND DISTRICT PERFORMANCE MEASURES
WILL BE PRINTED.


ENTER COMMAND:
>PRNT_TR


TRAVEL MATRIX WILL NOT BE PRINTED.
```

```
ENTER COMMAND:
>PRNT_VST


VARIABLE SERVICE TIME DATA WILL BE PRINTED.


ENTER COMMAND:
>SAVE

DO YOU WANT TO COMPUTE THE OUTPUT MEASURES AT
THIS TIME?>Y
ENTER NAME OF REGION FILE (I.E., THE NAME OF THE FILE THAT
CONTAINS GEOGRAPHIC AND CALL VOLUME DATA FOR EACH REPORTING
AREA IN THE REGION OF INTEREST)>LAWCITY
ENTER NAME OF DISTRICT PLAN (I.E., THE NAME GIVEN TO THE DISTRICT
PLAN CREATED USING THE MONITNEW OR MONITOLD COMMAND)>EX8
ALL OUTPUT REQUESTED IN EX8 CAN BE PRINTED AT YOUR TERMINAL
AS IT IS GENERATED BY THE HYPERCUBE PROGRAM, OR IT CAN BE
STORED FOR LATER RETRIEVAL. DO YOU WANT THE OUTPUT STORED?>N
EXECUTION:



SERVICE TIME FOR EACH BEAT CAR
BEAT CAR        1      20.00 MINUTES
BEAT CAR        2      30.00 MINUTES
BEAT CAR        3      30.00 MINUTES







MODIFIED CENTER-OF-MASS DISPATCHING

FIRST PREFERENCE ASSIGNED TO BEAT CAR
   ASSOCIATED WITH EACH BEAT
PROBLEM TITLE: EXERCISE 8 - ADD 2ND MAN TO EX3 CAR 1
UNLIMITED CAPACITY QUEUE WITH 1_ST-COME 1_ST-SERVED QUEUE DISCIPLINE
IN-QUEUE TRAVEL TIMES  ONLY APPROXIMATE DUE TO UNEQUAL SERVICE TIMES
RUN NUMBER:  1
BEAT CAR               ...TOTAL NUMBER OF =  3
RPT AREA  ...TOTAL NUMBER OF =  16
AVERAGE SERVICE TIME=  25.71 MINUTES
AVERAGE NUMBER PER HOUR OF CALLS FOR SERVICE  =   3.000
AVERAGE NUMBER PER  25.71 MINUTES OF CALLS FOR SERVICE  =   1.286
SPEED OF PATROL=   7.50 MPH
AVERAGE UTILIZATION FACTOR
   (IN THE CASE OF UNLIMITED LINE CAPACITY)=  0.429

REGION-WIDE AVERAGE TRAVEL TIME=   [illegible].135 MINUTES
```

AVERAGE TRAVEL TIME FOR QUEUED CALLS=   4.111 MINUTES
PROBABILITY OF SATURATION= 0.16610
REGION-WIDE AVERAGE WORKLOAD (% TIME BUSY)= 0.42732
STANDARD DEVIATION OF WORKLOAD=   0.035
MAXIMUM WORKLOAD IMBALANCE= 0.06661

FRACTION OF DISPATCHES THAT ARE INTER-BEAT = 0.37044

REGION-WIDE AVERAGE PATROL FREQUENCY=   0.259 PASSES PER HOUR

PERFORMANCE MEASURES THAT ARE SPECIFIC TO EACH BEAT CAR

ID OF BEAT CAR NAME	NO	WORKLOAD OF UNIT	% OF MEAN	FRACTION OF DISPATCHES OUT OF BEAT	% OF MEAN	AVERAGE TRAVEL TIME
BEAT CAR	1	0.438	102.6	.1724	46.5	2.862
BEAT CAR	2	0.455	106.5	.5649	152.5	3.190
BEAT CAR	3	0.388	90.9	.4587	123.8	3.722

PERFORMANCE MEASURES THAT ARE SPECIFIC TO EACH BEAT

ID OF BEAT NAME	NO	WORKLOAD OF BEAT	% OF MEAN	FRACTION OF DISPATCHES INTER-BEAT	% OF MEAN	AVERAGE TRAVEL TIME
BEAT	1	0.710	165.7	.3673	99.2	3.215
BEAT	2	0.294	68.6	.4077	110.1	2.843
BEAT	3	0.282	65.7	.3412	92.1	3.503

ALL DONE

CORE RESET TO 256
CSS.300 06/15/76

APPENDIX D

SUMMARY OF HYPERCUBE COMMANDS, FILES, AND INPUT DATA

NCSS Commands [1,3]	Hypercube Commands [1,4]	Monitor Commands [2,5]	
ALTER (52)	BRFLIST (99)	ADJUST (67)	PRNT_ALL (78)
KL (37)	CANCEL (94)	BACK (72)	PRNT_ATOM (79)
LINK (38)	CONLIST (99)	COMPARE (69)	PRNT_CFS (79)
LISTF (52)	CORREG (57)	CONFIG (65)	PRNT_COST (79)
LOGOFF (39)	DELETE (54)	CORTM (74)	PRNT_PATROL (79)
PRINTF (52)	HYPERCUBE (92)	CREATE (82)	PRNT_SP_ALC (79)
SET CORE (63)	LISTALL (98)	D_SCALE (73)	PRNT_TR (79)
STAT (92)	LISTHYP (98)	EXIT (83)	PRNT_TT (79)
	MODPLAN (87)	FRONT (72)	PRNT_VST (79)
	MODREG (57)	FRST (70)	QUEUE (70)
	MONITNEW (63)	GLOSSARY (75)	SAVE (82)
	MONITOLD (64)	INSPECT (78)	SPEED (65)
	NEWPLAN (85)	LISTADVCMDS (82)	STATISTICS (80)
	NEWREG (56)	LISTCMDS (82)	STORE (82)
	OVERNITE (94)	MIDDLE (72)	SUMMARY (80)
	VERYBRF (99)	MODIFY (82)	TITLE (75)
		NO_PRNT (78)	TXOV (73)
		PATROL (66)	TYPOUT (80)
		POLICY (68)	VST (66)
		PRINTDIST (78)	WORKLOAD (66)

[1] Commands are valid only after the computer prints time-of-day.

[2] Commands are valid only after the computer prints ENTER COMMAND: within the monitor program.

[3] Commands performing the same functions as these NCSS commands are likely to be available on time-share systems other than NCSS although the command names and formats for their use will probably be different.

[4] Additional programming will be required for use of software on time-share systems other than NCSS in order to perform the functions of these commands.

[5] Commands are independent of the system on which the software is implemented.

Figure D-1

COMMANDS COMPRISING THE HYPERCUBE SYSTEM

File Name	Type of File (Region, District Plan, Output)	Date Created	Date Deleted	Description of Contents (e.g., Applicable Precinct and Watch, Associated Region File, Etc.)

Figure D-2

SAMPLE LOG FOR RECORDING FILES

Description of Data	Optional or Required	Unit of Measurement	Restrictions	Comments
Region File				
1. Reporting area identifiers	Optional	--	Numeric, less than or equal to 999999	Sequential numbering assumed if omitted
2. X, Y coordinates	Required	Arbitrary	Limited to six characters or less including the decimal point	D-SCALE command is used to specify a multiplicative constant used to convert coordinates to miles
3. Size of reporting areas	Optional	Square miles	Limited to six characters or less including the decimal point	Computed intra-reporting area travel times zero if omitted
4. Relative workloads	Required	Arbitrary	Limited to six characters or less including the decimal point	Computer automatically normalizes workloads
5. Patrolable street miles	Optional	Miles	Limited to six characters or less including the decimal point	

Figure D-3

HYPERCUBE INPUT DATA

District Plan File

Description of Data	Optional or Required	Unit of Measurement	Restrictions	Comments
1. Number of units	Required	--	Between 1 and 15 if the exact model is used, and between 1 and 34 otherwise	Indirectly specified by user definition of district configuration
2. Number of reporting areas	Required	--	Limited by cost and storage considerations only	
3. Title of district plan	Required	--	50 characters or less	Appears in hypercube output; independent of the name of the district plan file
4. Response speeds	Optional	Miles per hour		One mile per hour assumed if not specified
5. Patrol speed	Optional	Miles per hour		Statistics on preventive patrol frequencies are not computed unless a patrol speed is specified
6. Patrol unit service time	Required	Minutes		

Figure D-3 (Continued)

Description of Data	Optional or Required	Unit of Measurement	Restrictions	Comments
7. Call rate	Required	Calls per hour	If calls are queued, the number of units, service time, and call rate must be such that region-wide utilization is not greater than 1.0	Statistics can be requested for several call rates by specifying a lowest arrival rate and an incremental arrival rate
8. Number of workload levels	Required	--	Maximum of 10	
9. Model to be used to compute statistics	Optional	--	Exact model can be used only if number of units is 15 or less	Approximate model assumed if not specified
10. Dispatch policy	Optional	--	Exact model required if AVL dispatching is specified	SCM dispatching assumed if not specified
11. Unit identifiers	Required	--	Numeric, non-zero, less than or equal to 32767	
12. Inter-reporting area travel times	Optional	Minutes		Manhattan metric used to compute travel times not specified
13. Dispatch costs	Optional	Arbitrary	Between 0 and 999, cannot be specified with AVL dispatching	Computed according to dispatch policy specified
14. Service times for individual response units	Optional	Minutes	Exact model required if variable service times are specified	

Figure D-3 (Continued

Description of Data	Optional or Required	Unit of Measurement	Restrictions	Comments
15. Proportionality constant used to compute intra-reporting area travel times	Optional	--		Computed intra-reporting area travel times zero if not specified
16. Scaling factor used to convert coordinates to miles	Optional	--		Scaling factor of one assumed if not specified
17. Glossary terms	Optional	--		Terms specified are used in hypercube output
18. Dispatch procedure when a unit other than the district car appears to be closest to an incident	Optional	--	Specified procedure is ignored if AVL dispatching is used	No special preference for district car if not specified
19. Procedure for handling calls when all units are unavailable	Optional	--	Number of units, service time, and call rate must be such that region-wide utilization is not greater than 1.0 if calls are to be queued	Queuing of calls is not allowed unless specified
20. Non-call-for-service	Optional	Minutes per hour units spend on non-call-for-service work		Zero non-call-for-service workload if not specified

Figure D-3 (continued)

Description of Data	Optional or Required	Unit of Measurement	Restrictions	Comments
21. Preventive patrol factors	Optional	--	Between 0.0 and 10.0, if specified the factor for at least one reporting area in district must be non-zero	Assumed proportional to reporting area workload if not specified, proportional to workload for overlay units

Figure D-3 (continued)

NUMBER OF REPORTING AREAS	NUMBER OF UNITS										
	3	6	9	12	15	18	21	24	27	30	33
25	240	243	245	248	251	253	256	259	261	264	266
50	251	256	260	265	270	275	280	285	289	294	299
75	266	273	280	287	295	302	309	316	323	330	337
100	287	296	305	315	324	333	342	352	361	370	379
125	312	324	335	347	358	369	381	392	404	415	427
150	343	356	370	383	397	411	424	438	452	465	479
175	378	394	409	425	441	457	473	489	504	520	536
200	418	436	454	472	490	508	526	544	562	580	598
225	463	483	503	523	544	564	584	604	624	645	665
250	512	535	557	580	602	625	647	669	692	714	737
275	567	592	616	641	666	690	715	739	764	789	813
300	627	654	680	707	734	761	788	814	841	868	895

*Storage requirements are specified in units of K-bytes where one K-byte = 1024 bytes.

Figure D-4

CORE STORAGE REQUIRED TO USE THE APPROXIMATE HYPERCUBE MODEL*

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

*Storage requirements are specified in units of K-bytes where one K-byte = 1024 bytes.

Figure D-5

CORE STORAGE REQUIRED TO USE THE EXACT HYPERCUBE MODEL WITH NON-AVL DISPATCHING*

NUMBER OF REPORTING AREAS	NUMBER OF UNITS													
	2	3	4	5	6	7	8	9	10	11	12	13	14	15
25	241	243	244	246	248	251	257	268	289	332	422	607	992	1794
50	253	255	258	261	264	268	275	287	309	354	444	630	1017	1819
75	270	273	277	281	285	290	298	311	334	380	471	658	1046	1849
100	292	296	301	305	311	317	326	340	364	410	503	691	1080	1884
125	318	324	329	335	341	349	359	374	399	446	540	729	1118	1924
150	350	356	363	369	377	385	396	412	439	487	581	772	1162	1969
175	386	393	401	409	417	427	439	456	483	533	628	819	1211	2018
200	427	436	444	453	463	473	486	504	532	583	679	872	1264	2073
225	473	483	492	502	513	524	538	557	587	638	736	929	1323	2132
250	524	535	545	556	568	580	595	615	646	698	797	992	1386	2197
275	580	592	603	615	628	641	657	678	710	764	863	1059	1454	2266
300	641	653	666	679	693	707	724	746	779	834	934	1131	1527	2340

*Storage requirements are specified in units of K-bytes where one K-byte = 1024 bytes.

Figure D-6

CORE STORAGE REQUIRED TO USE THE EXACT HYPERCUBE MODEL WITH AVL DISPATCHING*

NUMBER OF UNITS													
2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1	1	1	1	1	2	3	5	9	17	33	65	129

*Storage requirements are specified in units of K-bytes where one K-byte = 1024 bytes.

Figure D-7

INCREMENTAL CORE STORAGE REQUIREMENT FOR EACH ADDITIONAL WORKLOAD LEVEL USING THE EXACT HYPERCUBE MODEL WITH NON-AVL DISPATCHING*

NUMBER OF REPORTING AREAS	NUMBER OF UNITS													
	2	3	4	5	6	7	8	9	10	11	12	13	14	15
25	1	2	2	2	3	3	4	5	8	12	20	37	69	133
50	2	3	3	4	5	6	7	8	11	15	24	41	73	138
75	3	4	5	6	7	8	9	11	14	19	28	45	78	142
100	4	5	6	7	9	10	12	14	17	22	32	49	82	147
125	4	6	7	9	11	12	14	17	20	26	35	53	86	152
150	5	7	9	11	13	15	17	20	23	29	39	57	90	156
175	6	8	10	12	15	17	19	22	27	33	43	61	95	161
200	7	9	12	14	16	19	22	25	30	36	46	65	99	165
225	8	10	13	16	18	21	24	28	33	39	50	69	103	170
250	8	11	14	17	20	24	27	31	36	43	54	73	108	175
275	9	12	16	19	22	26	30	34	39	46	57	77	112	179
300	10	13	17	21	24	28	32	37	42	50	61	81	116	184

*Storage requirements are specified in units of K-bytes where one K-byte = 1024 bytes.

Figure D-8

INCREMENTAL CORE STORAGE REQUIREMENT FOR EACH ADDITIONAL WORKLOAD LEVEL USING THE EXACT HYPERCUBE MODEL WITH AVL DISPATCHING*

Number of Lines in Output File	Core Storage Required to List Output File*
0-1500	256
1500-2000	320
2000-2700	384
2700-3700	448
3700-4700	512
4700-5000	576

*Storage requirements are specified in units of K-bytes where one K-byte = 1024 bytes.

Figure D-9

CORE STORAGE REQUIRED TO LIST OUTPUT FILES
USING THE "LISTHYP," "BRFLIST," OR "VERYBRF" COMMANDS

APPENDIX E

HYPERCUBE FLOW CHARTS

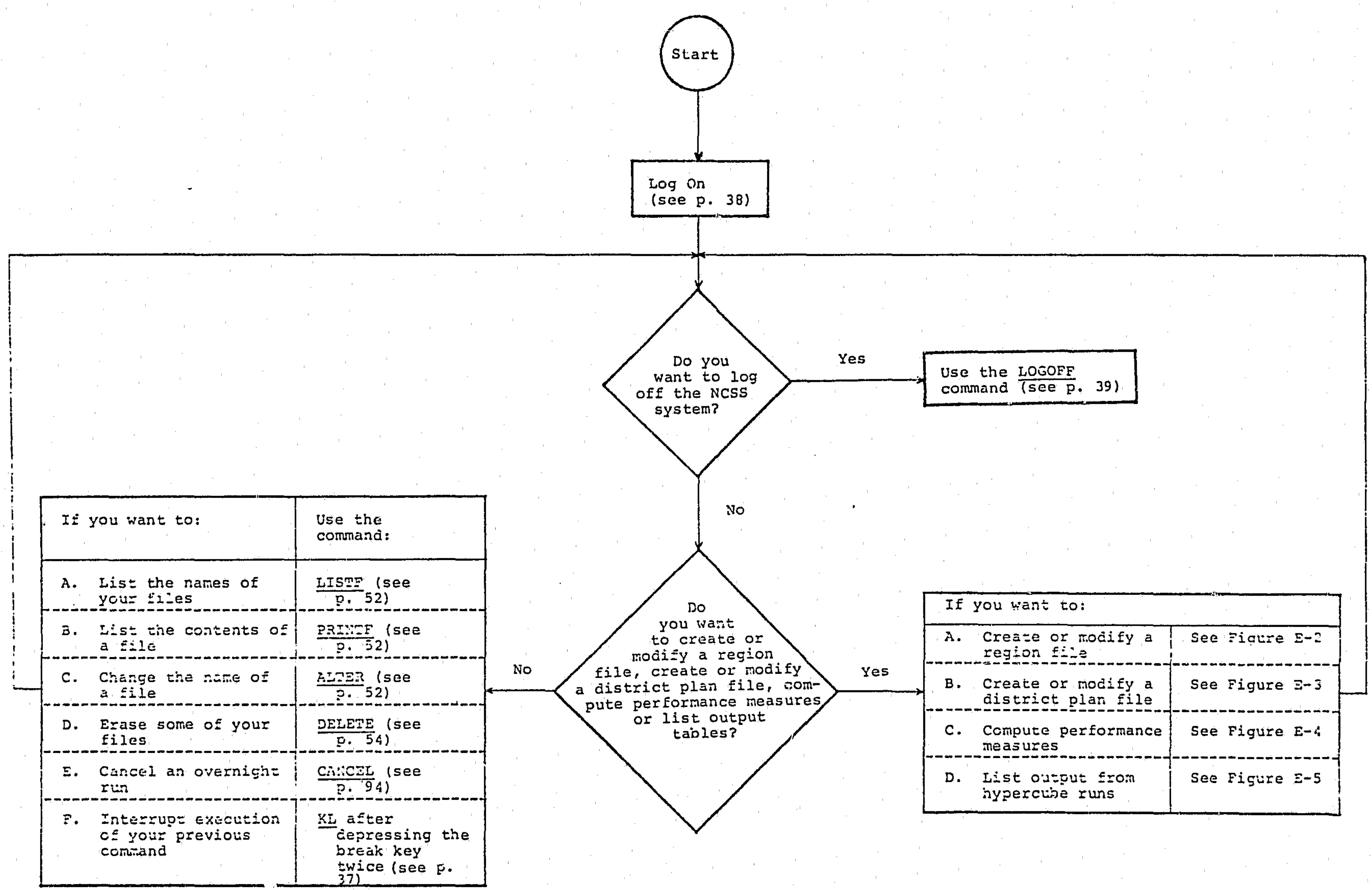
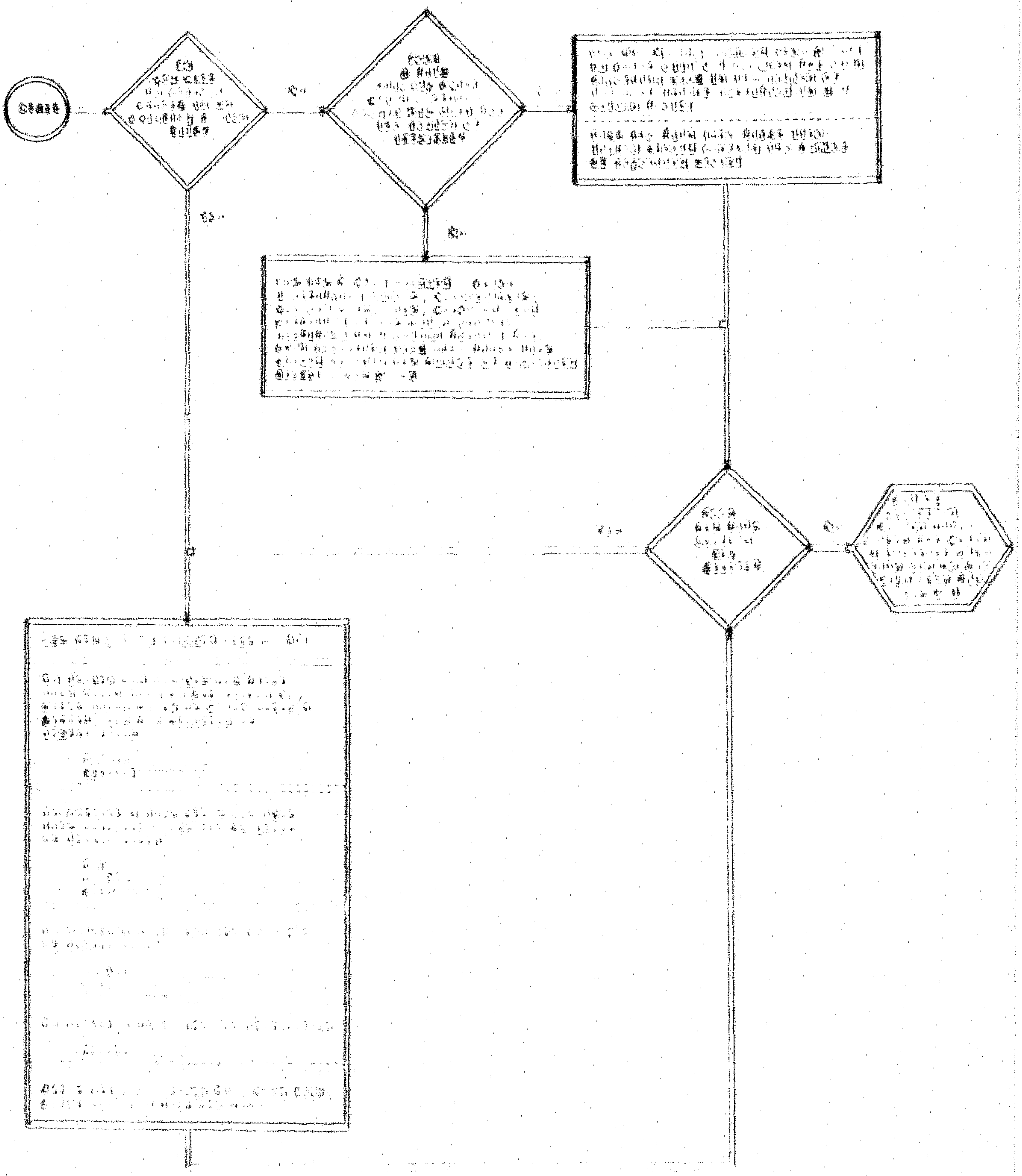


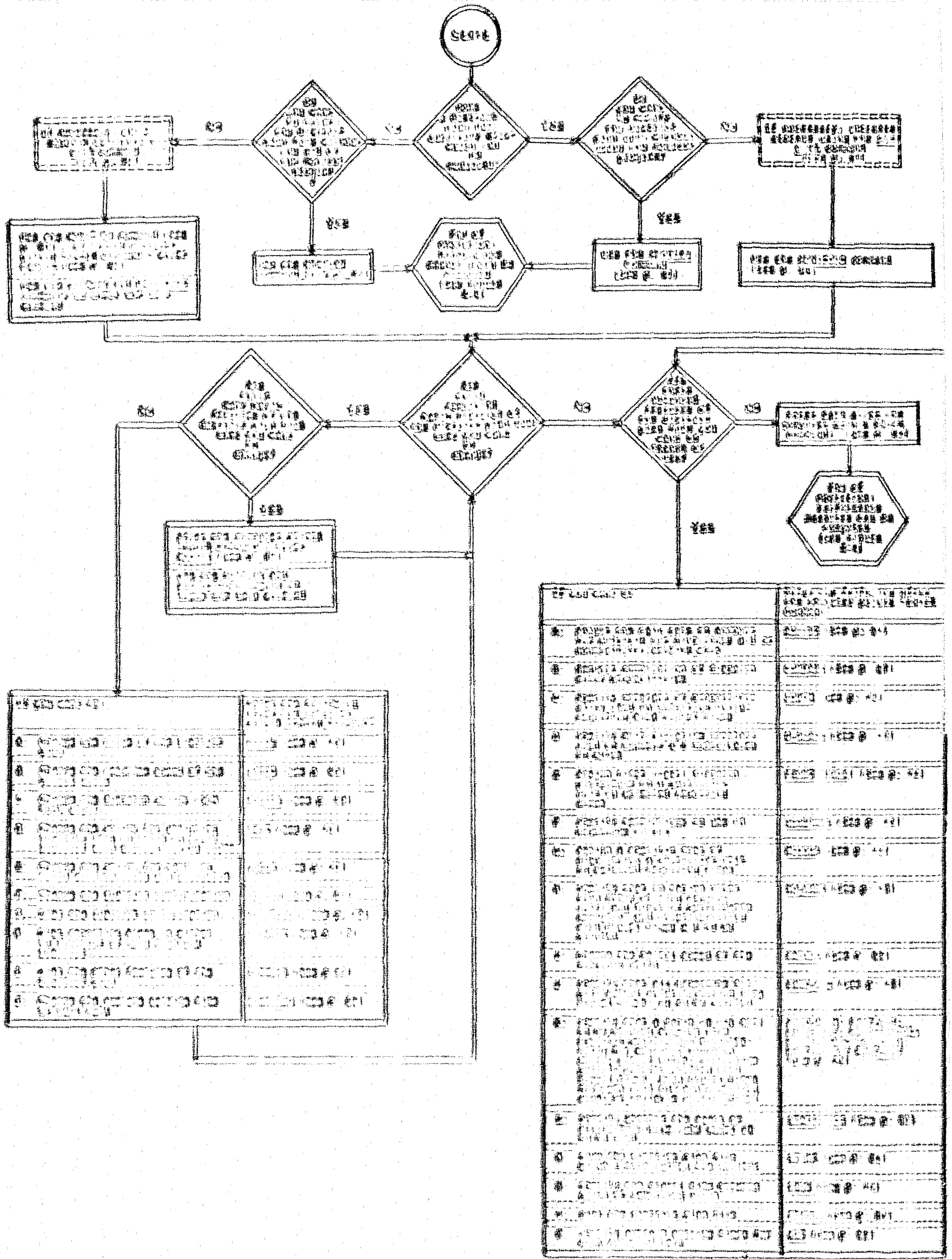
Figure E-1

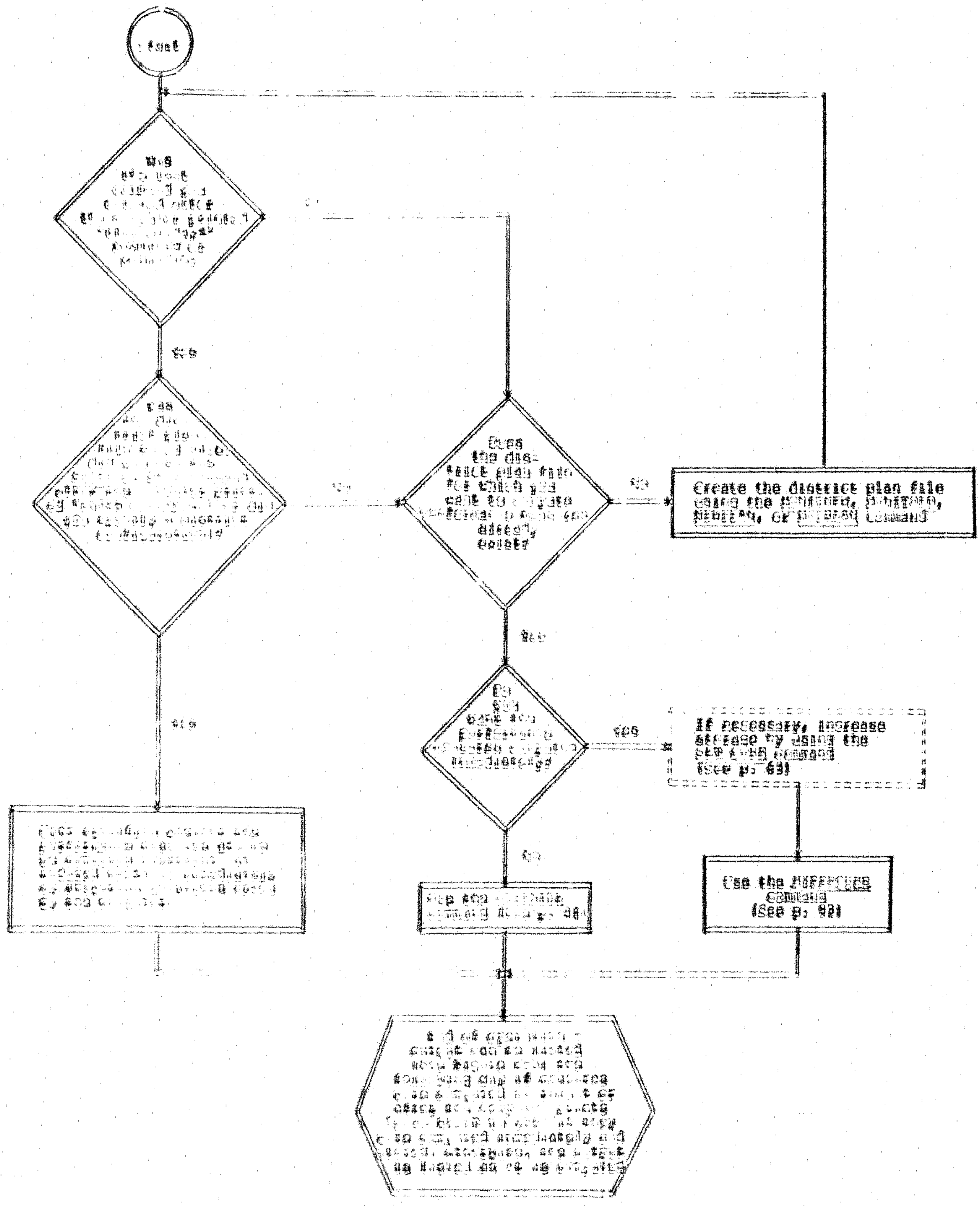
HYPERCUBE OPERATIONS

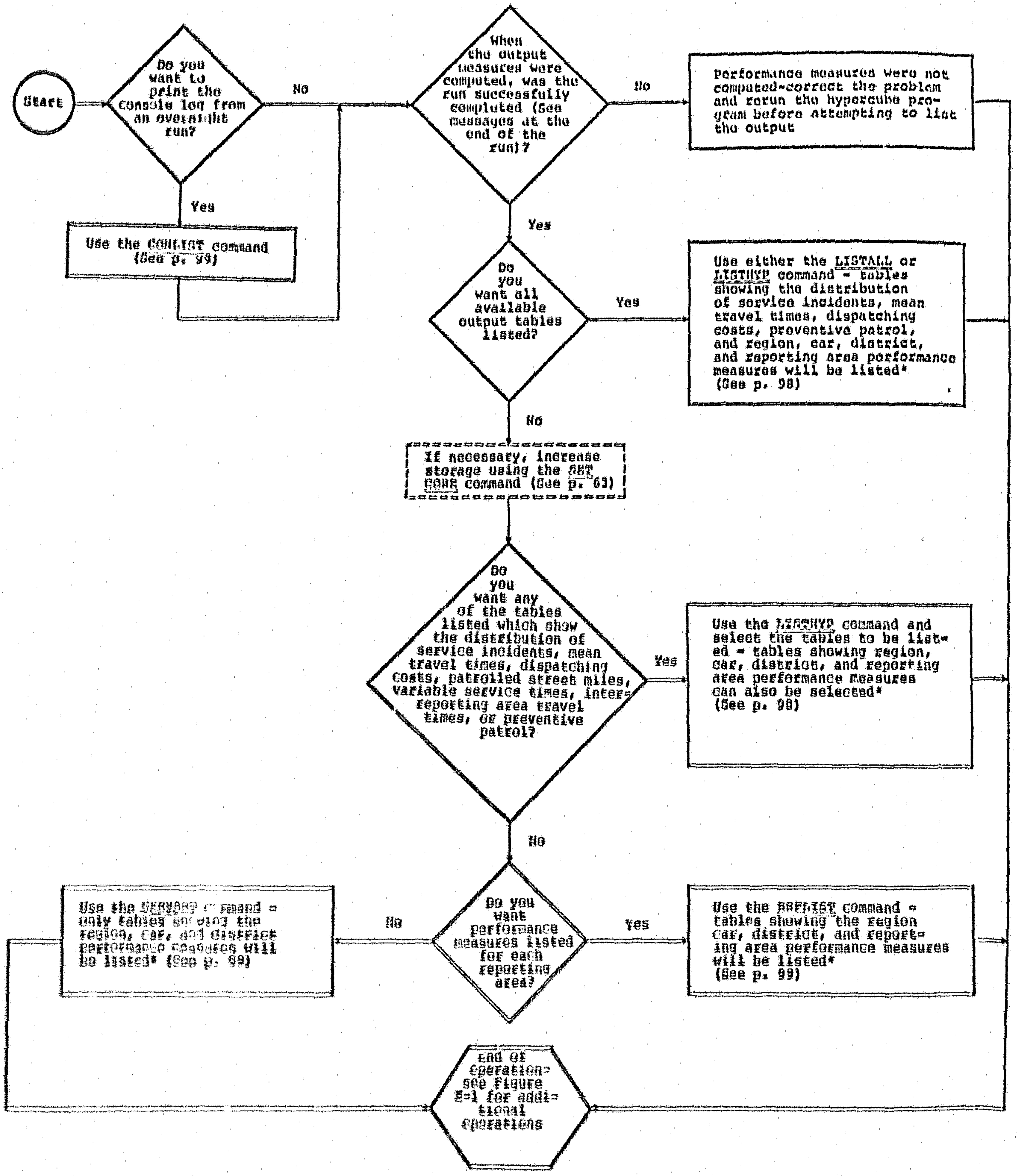
CONTINUED

3 OF 3





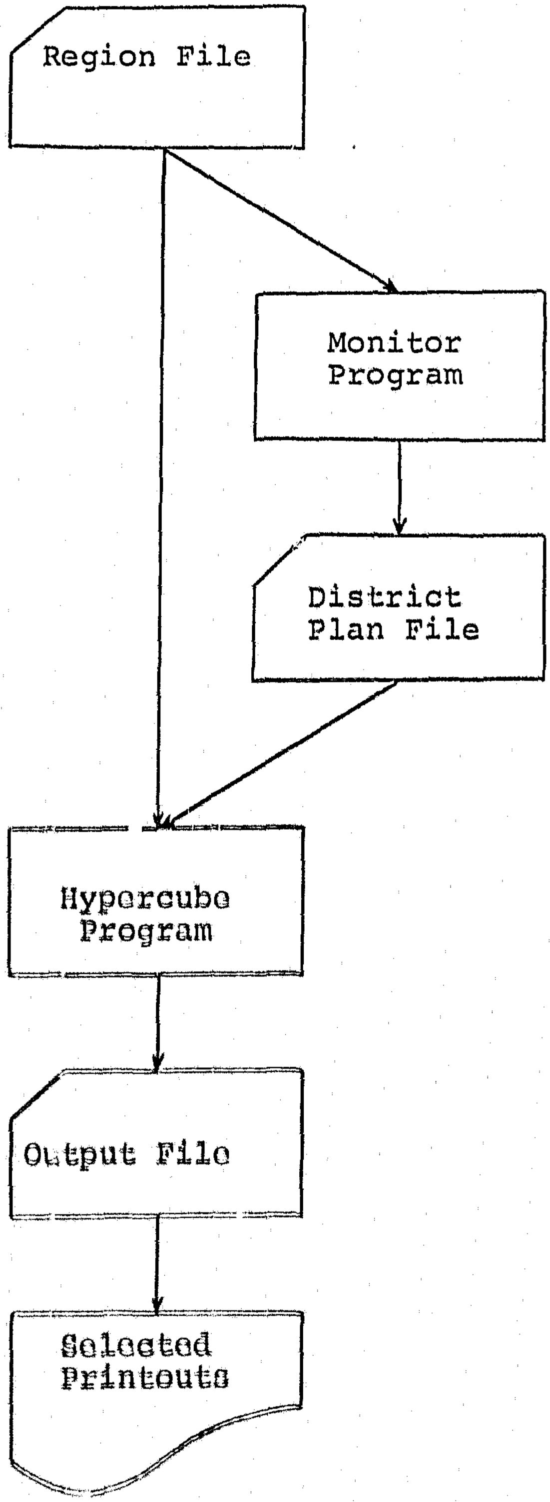

Create the district plan file
If necessary, increase storage by using the



*User's requests to list tables for which a corresponding request to generate these tables was not included in the district plan file, are ignored.

Figure B-5

LISTING STORED HYPERCUBE OUTPUT



Region File: Contains geographic and call volume data for region being analyzed - manipulated using the "ALTER," "CORREG," "DELETE," "LISTF," "MODREG," "NEWREG," and "PRINTF" commands (see Chapters V and VI)

Monitor Program: Creates district plan files from user description of patrol operations - invoked using the "MONIT-NEW" and "MONITOLD" commands (see Chapter VI)

District Plan File: Contains description of district configuration and patrol operations - manipulated using the "ALTER," "DELETE," "LISTF," "MODPLAN," "NEWPLAN," and "PRINTF" commands (see Chapters V and VI)

Hypercube Program: Computes performance measures for specified region and district plan files - controlled using the "CANCEL," "CONLIST," "HYPERCUBE," and "OVERNITE" commands (see Chapters VII and VIII)

Output File: Contains output generated by the hypercube program - manipulated using the "ALTER," "BRFLIST," "DELETE," "LISTALL," "LISTF," "LISTHYP," and "VERYBRF" commands (see Chapter VIII)

Selected Printouts: Output tables printed according to user specifications (see Chapter VIII)

Figure E-6

SCHEMATIC REPRESENTATION OF HYPERCUBE FILES, PROGRAMS, AND COMMANDS

END