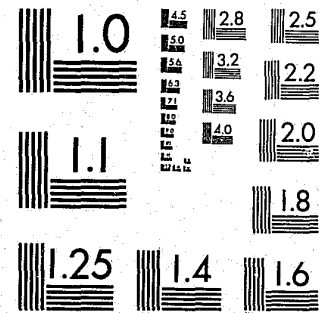National Criminal Justice Reference Service

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SCHEDULING POLICE MANPOWER BY COMPUTER

Nelson B. Heller, Project Director
Thomas McEwen, Assistant Director
Office of the Chief of Police
St. Louis Metropolitan Police Department
St. Louis, Missouri

William Stenzel, Graduate Student
Philip Zwart, Associate Professor
Department of Applied Mathematics
and Computer Science
Washington University
St. Louis, Missouri

ABSTRACT

In October 1970 the St. Louis Metropolitan Police Department put into operation a new type of work schedule in its 20-man Evidence Technician Unit. The schedule, called a "proportional rotating schedule" because it distributes the manpower by day and watch in proportion to the demand for service, has a number of features which represent improvements over previously used schedules. Included are: (1) identical patterns of days worked and days off for all men; (2) the capability, in designing the schedule, to control the lengths of periods of consecutive days worked and consecutive days off, and the number and distribution of weekends off; and (3) a computer-based design procedure which, by this summer when programming is completed, is expected to reduce schedule design time to only that required to specify the type of schedule desired and to collect the necessary workload data.

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SCHEDULING POLICE MANPOWER BY COMPUTER

I. Introduction

This paper reports recent developments in the St. Louis Metropolitan Police Department's program to devise improved work schedules for its officers. The improvements sought include (1) the achievement of manning levels each day and watch which are proportional to the anticipated workload; (2) identical patterns of days worked and days off for all officers; (3) the capability, in designing the schedule, to control the lengths of periods of consecutive days worked (called work periods) and consecutive days off (called recreation periods), and to control the number and distribution of weekends off; and (4) a computerized schedule design procedure.

The research program, under way since January 1968, has produced a new type of work schedule called a "proportional rotating schedule" which incorporates all of the desired improvements. A test schedule was put into operation in October 1970 in the Department's 20-man Evidence Technician Unit. In December 1971, after having operated successfully for 14 months, the schedule was updated on the basis of changes in the distribution of work over the week. A March 1972 survey of unit officers, discussed below, indicates favorable acceptance of the new schedule.

II. The 1972 Evidence Technician Unit Work Schedule

Proportional rotating schedules are illustrated by using the 1972 Evidence Technician Unit (ETU) schedule. The ETU, a component of the Department's Laboratory Division, operates evidence collection vans around the clock, one in each of the city's three police field operations "Areas." The vans, whose personnel perform preventive patrol activities between assignments, are dispatched to crime scenes when requested by beat patrol officers responding to the incident.

Under Department regulations, officers receive two days off for every five days worked. Each man also is given six days off for paid holidays plus a three-week vacation each year. ETU officers rotate watch assignments after a specified number of weeks on each watch. An exception was made in the 1972 schedule for two officers attending school during the day watch (7 a.m. – 3 p.m.): one was assigned permanently to the afternoon watch (3 p.m. – 11 p.m.), the other to the night watch (11 p.m. – 7 a.m.).

Data on the 10,132 incidents to which the ETU responded in 1971 were used to construct the 1972 schedule. A table of the distribution of work over the week for 1971 is shown in Figure 1.

Figure 1 - Percentage Distribution of
ETU Incidents Over the Twenty-one Watches
of the Week for 1971

Watch	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.	Sun.	Total
Day (7 a.m.-3 p.m.)	5.1	4.3	4.8	4.3	5.1	4.5	4.3	32.5%
Afternoon (3 p.m.-11 p.m.)	5.4	5.1	5.5	5.0	5.4	4.5	4.4	35.3%
Night (11 p.m.-7 a.m.)	4.1	4.3	4.5	4.8	5.3	5.1	4.0	32.2%
Total	14.6	13.8	14.9	14.1	15.8	14.2	12.7	100.0%

The total number of duty manwatches available each week in a unit of N officers is given by the formula,

$$T = 5N - H$$

where H is the average number of manwatches per week lost to days off for paid holidays. For a unit of 20 men H is approximately two. Consequently, for the ETU T equals 98 manwatches. Using the information in Figure 1 as a basis, manwatches were distributed as shown in Figure 2. Vacations were scheduled on the day and afternoon watches, requiring that the manning levels on these watches be kept as high as possible.

The basic rotation and recreation schedule developed for the unit is shown in Figure 3. The schedule consists of an 18-week rotating schedule for the 18 officers who rotate watches, and a fixed schedule for the 2 officers permanently assigned to the afternoon and night watches. The schedule operates as follows: the 18 officers are assigned man numbers from 1 to 18 (based on their choice of vacations, as explained further below). During the first week of schedule operation, each officer works the schedule for the week bearing his number. For example, man 9 works week 9, a day watch assignment on which he works Monday through Thursday and is on recreation Friday, Saturday, and Sunday. On the second week of operation each man advances to the next numbered week in the schedule,

Figure 2 - Manwatches for the
Twenty-one Watches of the Week
for the 1972 ETU Schedule
(Total Manwatches = T)

Watch	Mon	Tue	Wed	Thu	Fri	Sat	Sun
Day	5	5	5	5	5	5	4
Afternoon	5	5	5	5	5	5	4
Night	4	4	4	4	5	5	4

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Figure 3 - Basic Rotation and Recreation
Schedule for the Evidence Technician Unit
for 1972 (R = recreation day)

WEEK	WATCH	MON	TUE	WED	THU	FRI	SAT	SUN
1	NIGHT		R	R	R			
2	NIGHT			R	R			
3	NIGHT					R	R	R
4	AFT							
5	AFT		R	R	R			
6	AFT					R	R	R
7	DAY	R	R	R	R			
8	DAY				R	R		
9	DAY					R	R	R
10	NIGHT							
11	NIGHT	R	R					
12	AFT	R	R					
13	AFT			R	R			
14	AFT					R	R	R
15	DAY						R	R
16	DAY							R
17	DAY	R						
18	DAY			R	R			
PERM.	NIGHT	R						R
PERM.	AFT	R						R

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with man 18 rotating back to week 1. Continuing the example for man 9: he moves to week 10, which is a string of 7 working days on the night watch. After 18 weeks each officer will have rotated once completely through every week of the schedule and returned to his initial week. Since all officers share the same basic rotation and recreation schedule, their individual schedules are identical, with the exception that they lag or lead each other by some number of weeks.

The two permanently assigned officers have their own schedule: each works Tuesday through Saturday every week and is off Sunday and Monday.

A number of additional features of the ETU schedule, described below, were requested by the unit commander and designed into the schedule.

A. The Number of Consecutive Weeks on any Watch

The number of consecutive weeks of assignment to any watch varies from a minimum of 2 on the night watch (weeks 9 and 10), to a maximum of 4 on the day watch (weeks 15 to 18). The selection of these periods depends on:

(1) The distribution of workload over the watches. Proportional rotating schedules make the duration of the assignment on each watch proportional to the workload. Thus officers spend a greater proportion of their time on the busier watches.

(2) The time required by officers to adjust to new working hours. Too frequent changes are fatiguing and disruptive of off-duty activities. Two weeks was considered the shortest acceptable assignment for the ETU.

(3) The number of consecutive weeks of assignment to the busiest watch and/or whichever other watch is considered least desirable by the officers. This is of particular concern to the younger officers who get last choice in the selection of vacations and who, having to settle for the winter vacations, fear assignment to the least desirable watch for most of the summer. Four weeks was considered the longest acceptable assignment for the ETU.

These considerations motivated selection of a schedule in which officers rotate twice through all watches during the 18 week rotation period, making the average stay on a watch three weeks in length.

B. Inclusion of One Seven-day Recreation Period

Once every 18 weeks officers receive a 7-day recreation period. In the master schedule this period runs from Friday of week 6 to Thursday of week 7. This feature, quite popular with the officers, gives each man a short vacation once every four months. For officers with winter vacations, the extended recreation period guarantees at least one week off during the warmer months.

C. Lengths of the Other Recreation Periods

Because recreation periods of one day's duration are considered unacceptable by the Department, two days is the shortest recreation period included in the ETU schedule. The maximum acceptable length of recreation periods is controlled to some extent by the maximum work period permitted. As the length of the average recreation period on a given watch increases, the number of these periods decreases, and the work period lengths must increase to take up the slack. For the ETU schedule, aside from the seven-day recreation period, it was decided that the longest recreation period would be three days.

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D. Maximum Number of Weekends Off

The schedule gives officers 5 weekends off in the 18 week rotation period: 3 Friday-Saturday-Sunday periods, 1 Saturday-Sunday period, and the weekend included in the 7-day recreation period. The schedule shows that each Saturday recreation day has been made part of a weekend off, hence the maximum number of weekends off has been achieved.

Weekends off have been spread as uniformly as possible over the rotation period. Only once do weekends off occur on consecutive weeks; otherwise the spacing between them varies from three to six weeks. Most weekends off occur just prior to the watch change points.

E. Watch Change Conditions

Officers rotate watches in the sequence of night, afternoon, day. The last day of assignment to any watch is always Sunday, officers commencing their new assignments on Monday. An officer scheduled to work on both Sunday and Monday at the watch change point faces one of two undesirable situations: the number of off-duty hours between the Sunday and Monday assignments will be either 8 or 32 (see Figure 4). An 8-hour interval does not give an officer adequate time to rest; a 32-hour interval is equivalent to a one-day recreation period.

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Figure 4 - Off-duty Hours Between Assignments
For Officers Working Sunday and Monday at
the Watch Change Point

| Watch Change | Hours Worked | | Off-duty Hours Between Assignments |
	Sunday	Monday	
Night to Afternoon	11 p.m. Sun - 7 a.m. Mon	3 p.m. - 11 p.m. Mon	8
Afternoon to Day	3 p.m. - 11 p.m. Sun	7 a.m. - 3 p.m. Mon	8
Day to Night	7 a.m. - 3 p.m. Sun	11 p.m. Mon - 7 a.m. Tues	32

Both situations may be avoided if either Sunday or Monday, or both, are included in recreation periods. Therefore, the ETU schedule has recreation periods immediately preceding or following five of its six watch change points. However, the change from the day watch on week 18 to the night watch on week 1 involves a 32-hour period between assignments.

F. Lengths of the Work Periods

Work periods in the ETU schedule vary in length from five to eight days. Of the 15 work periods in the 18-week cycle, only one is 8 days long. This represents a substantial improvement over other schedules in the Department in which officers experience 11-day work periods about three times a year.

G. Vacations

Vacations occur during either weeks 12 to 14 or 15 to 18 of the basic rotation and recreation schedule. The three-week vacation periods, one on the afternoon watch and the other on the day watch, are indicated by dotted lines in Figure 3. Prior to implementation of the ETU schedule a chart showing the vacation period for each man number was posted for examination by the officers. Officers are ranked according to decreasing seniority and select their vacations in this order. The vacation selected then identifies the officer's man number.

Vacation periods on each watch are non-overlapping so that manning will be reduced by no more than one man per watch during vacations.

Figure 5 shows the format in which the schedules were issued to the officers. Each schedule indicates the recreation days for the full year and the vacation period for the stated man number.

III. The Pros and Cons of Proportional Rotating Schedules

Certain features of proportional rotating schedules, useful for some applications but undesirable for others, are discussed next. The results of a questionnaire survey of the ETU, made in March 1972 to assess the officers' feelings regarding a number of these points as they apply to the 1972 ETU schedule, are also given.

A. Length of Assignment to Each Watch

For any proportional rotating schedule, the length of assignment to any watch will depend on several factors: work-load proportion on each watch, number of officers assigned permanently to watches, number of watch rotations in the rotation period, and its length. Usually the length of assignment will vary from watch to watch.

FIGURE 5 – 1972 ETU RECREATION SCHEDULE   Vacation: 3/20-4/9

JANUARY — NIGHT / AFTERNOON

SU	M	TU	W	TH	F	SA
..	..	4	5	6	..	1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30	31	..	..	..	..	..

FEBRUARY

SU	M	TU	W	TH	F	SA
..	..	1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	..	..	..	..

MARCH — DAY

SU	M	TU	W	TH	F	SA
..	..	..	1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	..

APRIL — VACATION / AFTERNOON

SU	M	TU	W	TH	F	SA
..	..	..	..	..	..	1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30	..	..	..	..	..	..

MAY — DAY / NIGHT

SU	M	TU	W	TH	F	SA
..	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31	..	..	..

JUNE — AFTERNOON / DAY

SU	M	TU	W	TH	F	SA
..	..	..	1	2	3	
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	..

JULY — DAY / N

SU	M	TU	W	TH	F	SA
..	..	..	..	..	..	1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30	31	..	..	..	..	..

AUGUST — DAY

SU	M	TU	W	TH	F	SA
..	..	1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	31	..	..

SEPTEMBER — NIGHT

SU	M	TU	W	TH	F	SA
..	..	..	..	..	1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30

OCTOBER — AFT

SU	M	TU	W	TH	F	SA
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31	..	..	..	..

NOVEMBER — DAY / N

SU	M	TU	W	TH	F	SA
..	..	..	1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	..	..

DECEMBER — AFTERNOON / DAY

SU	M	TU	W	TH	F	SA
..	..	..	..	..	1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30
31	..	..	..	..	..	..

MAN 1

Watches: D = Day, A = Afternoon, N = Night
Recreation days are circled; Vacation: March 20 – April 9

For the ETU schedule, watch assignments ranged from two to four weeks in length. The survey showed that at least three-quarters of the Unit found this quite acceptable:

	Yes	No
Object to variation	25%	75%
Some watches too short	25%	75%
Some watches too long	15%	85%

B. Individualized Schedules

Although the basic recreation and rotation schedules are identical for all officers, each ETU officer is always some number of weeks ahead of or behind each of the other officers. As a result, all officers do not change watches together and do not work with the same group each watch. In the course of a complete rotation through the schedule, every officer shares a number of on-duty shifts with almost every other officer in the unit. Regarding their individualized schedules, about a quarter of the ETU officers responded unfavorably in the questionnaire:

	Yes	No
Object to working with different members of the unit each watch	25%	75%
Object to changing watches at different times	20%	80%

C. Lengths of Work and Recreation Periods

The procedure for designing proportional rotating schedules permits the lengths of work and recreation periods to be controlled to a great extent. In most cases excessively long or short periods may be avoided entirely, the maximum number of weekends off may be given, and extended recreation periods may be readily included, if desired. On these aspects, most ETU officers responded favorably:

	Yes	No
Maximum work period of eight days is an improvement	85%	15%
Lengths of recreation periods acceptable	65%	35%
Object to 7-day recreation period	20%	80%
Frequency of weekends acceptable	58%	42%
Desire more recreation periods with Saturday or Sunday but not both	7%	93%

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D. Overall Assessment of Schedule

Regarding their relative preference for the ETU schedule compared to other schedules under which they have worked, three-fifths of the officers responded favorably:

	Yes	No
Prefer ETU schedule to all others	60%	40%
Generally satisfied with vacation scheduling for ETU	65%	35%
Fair distribution of workload per man each watch	74%	26%

IV. The Computer Programs

Input to the schedule design programs consists of data on the distribution of demand for service by hour or watch of the week, the number of officers to be scheduled, and the following design constraints (specified by the unit commander):

(1) the minimum and maximum number of officers permitted each day on each watch;

(2) the starting and terminal hours for each watch;

(3) the minimum and maximum lengths of recreation and work periods; and,

(4) the length of the rotation period, and the number of rotations through the watches during the rotation period.

A sequential procedure is used to design the schedules or to discover that the constraints are so severe that no satisfactory schedule exists. If no feasible schedule can be found for a given set of design constraints, the unit commander decides which constraints may be relaxed. The procedure is repeated until an acceptable recreation and rotation schedule is found. The final step is to design the vacation schedule. The computer programs are being written in Fortran for the Department's IBM 7040 and 370/155 systems.

V. Conclusions

In summary, the following features were achieved in the 1972 ETU schedule.

(1) proportional manning by day and watch;

(2) identical basic schedules for all officers;

(3) rotating watch assignments for 18 officers and permanent assignment for 2;

(4) watch assignments ranging from two to four weeks in length;

(5) recreation periods of two and three days, plus one seven-day period;

(6) five weekends off in the 18-rotation period, the maximum number possible;

(7) recreation periods immediately preceding or following five of the six watch change points;

(8) work periods varying in length from five to eight days; and,

(9) adequately-scheduled vacations.

Proportional rotating schedules should be applicable to many types of service operations besides law enforcement, including hospital nursing services, refuse collection, baggage handling, reservation operations, and toll collection. The computer programs being developed for schedule design allow construction and comparison of alternative schedules in a fraction of the time now required. Besides providing better control of the lengths of rotation and recreation periods, these schedules may substantially increase efficiency through their capability to distribute manpower resources over the week more proportionately to the demand for service.

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