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PATROL OPERATIONS OF BURNABY/RCMP DETACHMENT ANALYSIS AND SIMULATION

COMPLETE REPORT

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*GUEST WORKER FROM RCMP

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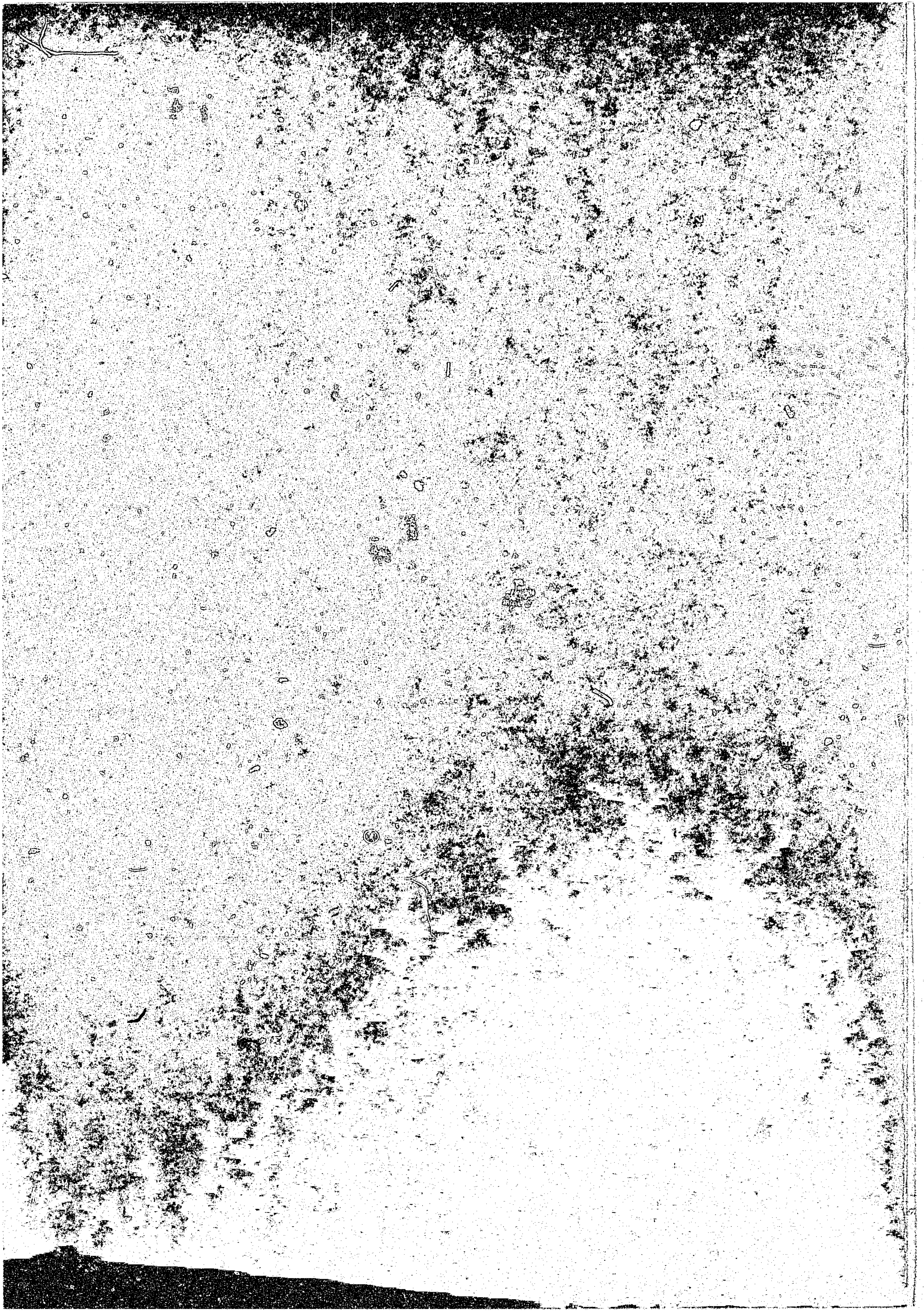
(A SUMMARY REPORT IS GIVEN IN ERB-886)

AUGUST 1975

RADIO AND ELECTRICAL ENGINEERING DIVISION

DIVISION DE RADIOTECHNIQUE ET DE GENIE ELECTRIQUE



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ABSTRACT

This report describes work carried out under the NRC-RCMP Patrol Deployment Project, whose objectives were to optimize patrol operations of the Detachment and to seek new research results. The map of Burnaby was divided into 368 small areas called "geographical atoms" or simply "atoms". Data on calls for service were obtained during a two-week period, and each call was classified according to time of receipt, nature and atom. Analysis of these data served as the basis for a set of 324 computer simulations in which the number of cars, arrangements of zones and number of calls for service were varied. The simulation results were used together with the data on calls to prepare patrol car and response time forecasting tables. Suggestions for improving patrol operations were made.

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F.R. Lipsett, A.F. Dalley and J.G. Arnold

COMPLETE REPORT

I. INTRODUCTION

The NRC-RCMP Patrol Deployment Project

This report describes work carried out under the NRC-RCMP Patrol Deployment Project. The project includes two RCMP Detachments—Burnaby and Red Deer (rural)—of which only the work in Burnaby is discussed here. The program is a continuation of work carried out with the Gloucester Police Force (1,2) and is similar to a project in progress with the Ottawa Police Force. The analysis and computer programs were similar to those used for the Gloucester work and originated in the work of Professor R.C. Larson of the Massachusetts Institute of Technology (3).

Use of Simulations

The simulations attempt to duplicate the operations of police patrols by mathematical operations carried out by a computer. Naturally only the mathematical, not the human, aspects of the patrol are dealt with. In the simulation it is assumed that calls for service arrive at a certain rate, that radio-equipped patrol cars are dispatched in answer to the calls, and that a certain time is taken for the patrol car to reach the scene of a call and to deal with it. If calls for service arrive at a low rate the patrolmen will have adequate time for preventive patrol. However, if calls arrive at a high rate it is unlikely that there will be enough patrol cars to answer each call as it is received, and calls will have to be placed in a queue.

At the outset, data obtained for the force under consideration are employed and the current operations of the force are duplicated as closely as possible. Then various factors are altered and their effects are observed. These may include the rate of calls for service, number of patrol cars on duty, alterations of the areas patrolled by the force, and so on. Thus the effect of a change in the strategy of the force, or the effect of a change in the area for which the force is responsible, may be deduced without the expense or difficulty of experiments on the force itself, or prior to implementation of a new strategy.

Burnaby

Burnaby is one of the municipalities of the Vancouver metropolitan region. The region includes approximately 1,000,000 people and is served by twelve police forces; Burnaby's population is approximately 150,000. It is bordered on the north by Burrard Inlet (an extension of Vancouver's harbour), on the east by Port Moody and Coquitlam, on the south by New Westminster and the Fraser River, and on the west by Vancouver. A large part of Burnaby is residential, along with substantial areas of light and heavy industry, several commercial areas, and Simon Fraser University. A large shopping center on the eastern boundary attracts customers from throughout the lower mainland of British Columbia.

II. DATA ON PATROL OPERATIONS

Method of Obtaining Data

All radio dispatchers and radio car officers on duty during the experimental period were briefed by the authors and asked to fill out forms giving details of all calls to which a car was dispatched. The form filled out by the dispatchers is shown in Fig. 1 and notes regarding it are given in Fig. 2. The form completed by the radio car officer is shown in Fig. 3 and notes concerning it (which appeared on the back) are given in Fig. 4. Occurrences to which cars were dispatched were classified according to a list given in Table I.

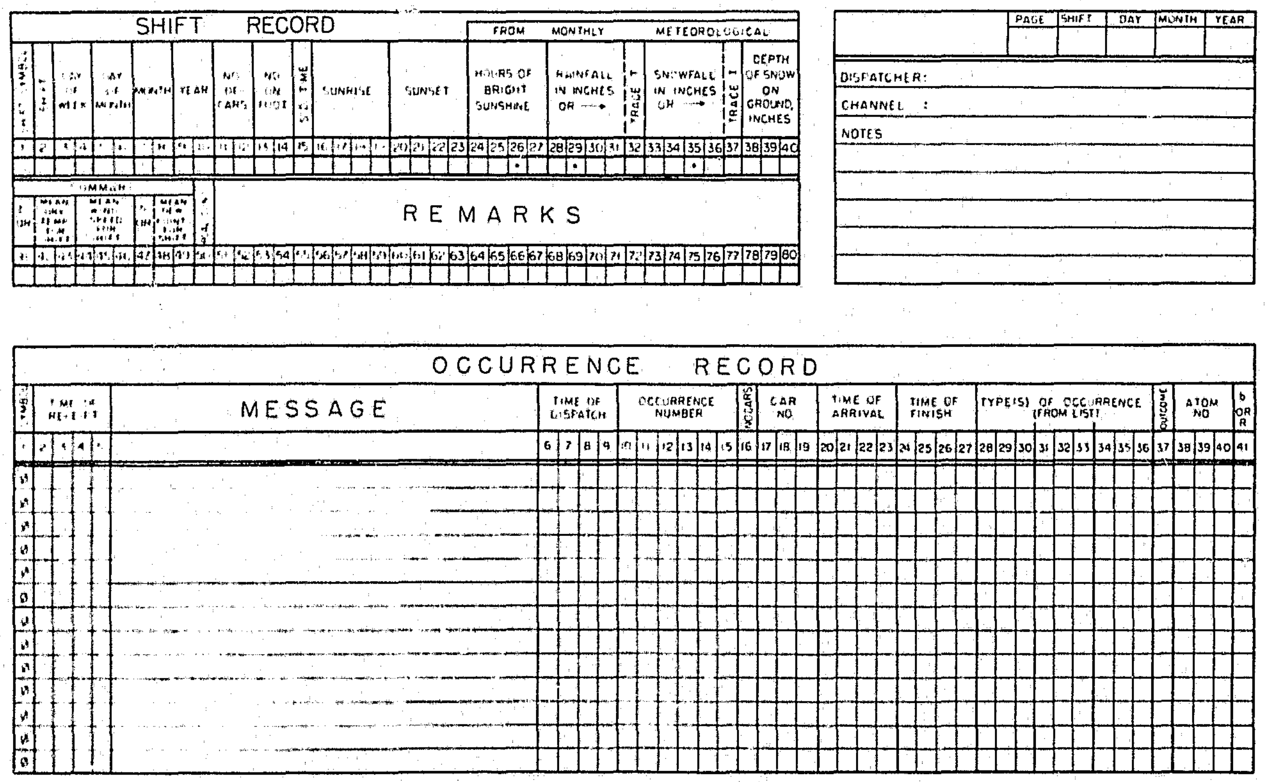

Fig. 1. Shift and occurrence records filled out by dispatchers during the data taking period 13–26 March 1974. (Shown reduced)

SHIFT RECORD

SPACE	
1	Shift symbol - to tell the computer a shift card is starting
2	Shift: Fill in 1, 2 or 3 1 1st relief 0715-1530 2 2nd relief 1515-2330 3 3rd relief 2315-0730 Date of 3rd relief is date at 2315 (preceding day) on dispatcher's sheets
3-4	Day of week: MO TU WE TH FR SA SU
5-6	Day of month: 01 02 03 04 31
7-8	Month: for Jan Feb Mar Apr May June July Aug Sept Oct Nov Dec fill in 01 02 03 04 05 06 07 08 09 10 11 12
9-10	Year: 73 74 ...
11-12	Number of cars starting shift: 01 02 99
13-14	Number of foot patrol officers on duty
15	Fill in S for Standard Time Fill in D for Daylight Saving Time
16-19	Time of sunrise in 24 hour time, from Weather Office table or newspaper
20-23	Time of sunset in 24 hour time, from Weather Office table or newspaper
24-27	Hours of bright sunshine from Monthly Meteorological Summary (MMS)
28-32	Rainfall in inches (or trace) from MMS
33-37	Snowfall in inches (or trace) from MMS
38-40	Depth of snow on ground, inches, from MMS
41	Blank (not filled in) if mean temperature of shift is zero or above zero - (negative) if mean temperature of shift is below zero
42-43	Mean temperature of shift (dry bulb), °F, calculated from hourly temperatures from MMS
44-46	Average wind speed for shift, mph, calculated from hourly wind speeds from MMS
47	Blank (not filled in) if mean dew point temperature of shift is zero or above zero - (negative) if mean dew point temperature of shift is below zero
48-49	Mean dew point temperature of shift, °F, calculated from hourly temperatures from MMS
50	Road conditions from following 1 Dry 2 Wet 3 Slushy 4 Loose snow 5 Packed snow 6 Icy Data to be obtained from Dept. of Transport records
51-80	Remarks. Keep short. If appropriate refer to additional remarks in note book or on log sheets. Examples of things to be mentioned include rain or snow storms, VIP visits, parades, riots, holidays, elections and so on.

OCCURRENCE RECORD

SPACE	
1	Occurrence symbol - to tell the computer an occurrence card is starting
2-5	Time of receipt of call for service at dispatcher's desk in 24 hour time Message: Address of occurrence, 10-code and other appropriate details
6-9	Time at which a car(s) is dispatched, 24 hour time
10-15	Occurrence number. May be filled in after completion of shift if not immediately available.
16	Number of cars dispatched
17-19	Car number
20-23	Time of arrival of car at scene of call, 24 hour time
24-27	Time at which call is completed, 24 hour time
28-36	Type of occurrence. Fill in one or more 3-digit numbers taken from the accompanying list. In case of doubt leave blank and make a remark
37	Outcome of call. Fill in the appropriate number chosen from the following: 1 gone on arrival 2 all in order 3 call completed by officer/no action/advised/settled on arrival 4 warning/ticket issued 5 arrest/charge/summons 6 report/continuing investigation
38-40	Atom in which the occurrence takes place. May be found from the atom-street directory or the atom maps.
41	Remarks. If no remarks are to be made leave the space blank. If remarks are to be made fill an R in the space and write the remarks in spaces 2-40 of the next row. If more space is required repeat this procedure. Remarks should be made when a high priority call is received; when a foot patrol officer (rather than a car) is sent; when a call is patrol-initiated (rather than citizen-initiated); when an arrest is made; or for any other appropriate reason.

Fig. 2. Shift and occurrence records notes

BURNABY (R.C.M.P.) POLICE DEPARTMENT

RADIO CAR LOG

Car No.	Members	Shift	Day	Month	Year	Page of

Stolen Autos Recovered ___	Warnings (Traffic) ___
Premises Checked ___	M.V. Accidents ___
Premises Insecure ___	Notes
CPIC Checks ___	
Arrests ___	
Charges (CC & Traffic) ___	

Time of Dispatch	Message & Remarks	Time of Arrival	Time of Finish	Outcome

Fig. 3. Log sheet filled out by radio car officers during the data taking period

Message and Remarks - Include appropriate details such as 10-code, address, name of caller, and nature of occurrence (as found after arrival).

Outcome of Call - Fill in the appropriate number chosen from the following:

1 gone on arrival
2 all in order
3 call completed by officer/no action/ advised/settled on arrival
4 warning/ticket issued
5 arrest/charge/summons
6 report/continuing investigation

Fig. 4. Notes on completing the log sheet of Fig.3. These were printed on the back of the log sheet.

TABLE I

List of occurrence types used by dispatchers completing occurrence records (Fig.1)

ADMINISTRATIVE	678
Meals	679
Refuelling	680
Repairs	681
Courier Service/Deliver Message	682
Transfer of Personnel	683
Transfer to Station	684
Directing Traffic	685
Traffic Signal Problem	686
Court	689
Escort (Funeral, VIP's)	692
ASSISTS	
Officer in Trouble	694
Other Forces (Criminal)	687
Other Agencies	690
Private Citizen in Distress	691
BREATHALYSER	696
DAMAGE TO PROPERTY/VEHICLES	614
Damage to Building	615
DISORDERLY, DISTURBANCE, ASSAULT, ETC.(080)	601
Fight	602
Loud Parties/Noise	603
Juvenile Loitering, Disturbances	604
Landlord-Tenant Dispute	605
Public Mischief/Neighbourhood Trouble	606
Indecent Assault (Male-061, Female-062)	607
Morality	608
DOG COMPLAINTS	
Barking Dog	616
Dog at Large (D.A.L.)	617
To Shelter (P.U.D.)	618
Injured, Sick or Dead	619
Bite	620
DOMESTIC TROUBLE	609
Husband-Wife	610
Boyfriend-Girlfriend	611
Unwanted Person	612
DOMINION SIGNAL	648
Burglar Alarm	650
Property Check/Insecure	693
DROWNING	636
DRUNKENESS	613
FIRE ALARM	626
GAS SICKNESS, ASPHYXIATION	634
Gas Leaks, Smells	635
HIT AND RUN DRIVER	644
HOLDUP, ROBBERY WITH VIOLENCE (091)	663
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TABLE I (cont'd)

7 March 1974

LOST OR MISSING PERSON	666
Adult or Teenager	667
Child	668
FOUND LOST OR MISSING PERSON	669
ELOPEE/INSTITUTION	670
MURDER (010)	665
OBSTRUCTION LANEWAY, SNOW CLEARING, ETC	645
Private Parking	646
Municipal Parking	647
PATROL-INITIATED CALLS	671
Walk-Stop	672
Car-Stop (Car Check)	673
Property Checks/Water Patrol	674
CPIC Check	675
Traffic Events	676
Serving Summons and Warrants	677
PEEPING TOM (TRESPASSING AT NIGHT)(193)	625
PERSON SICK ON STREET, PUBLIC CONVEYANCE, ETC	637
General Medical Emergency	638
Heart Attack	639
Suicide Attempt	640
Slumper	641
Death	642
PERSON USING FIREARMS (OFFENSIVE WEAPONS)(180)	631
Explosives	632
Other Weapons	633
Bomb Scare	688
PURSE SNATCHING	655
RAPE (050)	664
SEE COMPLAINANT	628
Obscene or Threatening Phone Calls	629
SHOPBREAKING, HOUSEBREAKING (B&E) (100)	660
Shopbreaking (in progress) (102)	661
Housebreaking (in progress) (101)	662
SHOPLIFTING (120)	654
STOLEN AUTOMOBILE (110)	656
Recovered Automobiles	657
Confirm Stolen Automobile	658
Removal of Abandoned Autos	659
SUSPICIOUS CHARACTER	621
Walking, Loitering	622
Vehicles	623
Noises	624
THEFT (over $200.00) (031)	697
THEFT (under $200.00) (036)	698
THEFT (MISCELLANEOUS)/NON-PAYMENT BILL (150)	651
Bogus Bills/Forged or NSF Cheque/ Stolen Credit Cards (152)	652
Recovery of Property (140)	653
TRAFFIC ACCIDENT, PERSON INJURED IN FALL, ETC	643

Results

The number of calls per day for the experimental period is given in Fig. 5. Saturday and Sunday were the busiest days of the week. The average number of calls per day was 102. The percentages of calls for various types of occurrences are given in Table II. At the time of data collection Burnaby was divided into the eight zones shown in Fig. 6. The atoms are also shown in Fig. 6. The number of calls received in each zone during the experimental period is shown in Fig. 7. The number per zone is fairly uniform, indicating that the present arrangement of zones is satisfactory. The number of calls per atom is given in Table III. It ranged from 0 to 40, but most atoms (70.4%) had 0 to 4 calls during the two-week period.

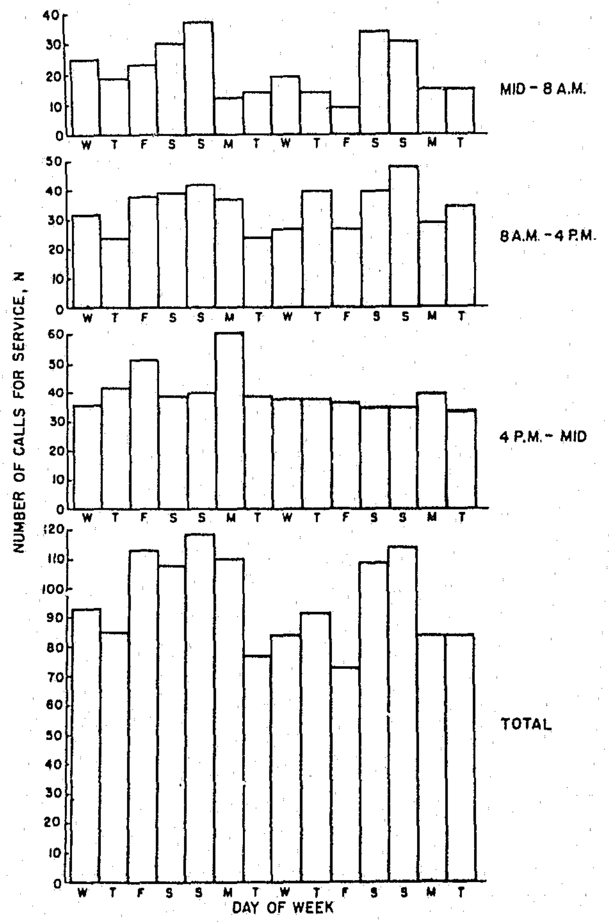

Fig. 5. Number of calls to which a radio car was dispatched for the whole of Burnaby, by time of day and day of week. The total number of calls was 1431 for the two weeks.

The number of calls per hour is given in Table IV and is shown in Fig. 8. The number varied from zero to twenty-one per hour, with the largest numbers of calls per hour on Sunday morning, Monday afternoon and Wednesday morning. The overall average was 4.3 calls per hour.

TABLE II

Distribution of dispatched calls for service

Total Number of Calls for Service		1431
Administrative		2.6%
Traffic Accidents		11.5%
Parking		2.5%
Criminal		
	Assault	13.4%
	Damage to Property	5.8%
	Theft Miscellaneous	2.2%
	Theft Over $200	2.2%
	Theft Under $200	9.7%
	Shoplifting	2.3%
	Stolen Auto	5.3%
	Break and Enter	3.7%
	Other	2.5%
	Total Criminal	47.1%
Non-Criminal		
	Domestic Trouble	1.2%
	Drunkenness	1.2%
	Suspicious Character	4.7%
	Fire Alarms	2.2%
	See Complainant	1.7%
	Medical Attention	2.4%
	Dominion Signal	4.0%
	Lost Person	2.9%
	Patrol Initiated Calls	10.1%
	Assists	4.9%
	Other	1.0%
	Total Non-Criminal	36.3%

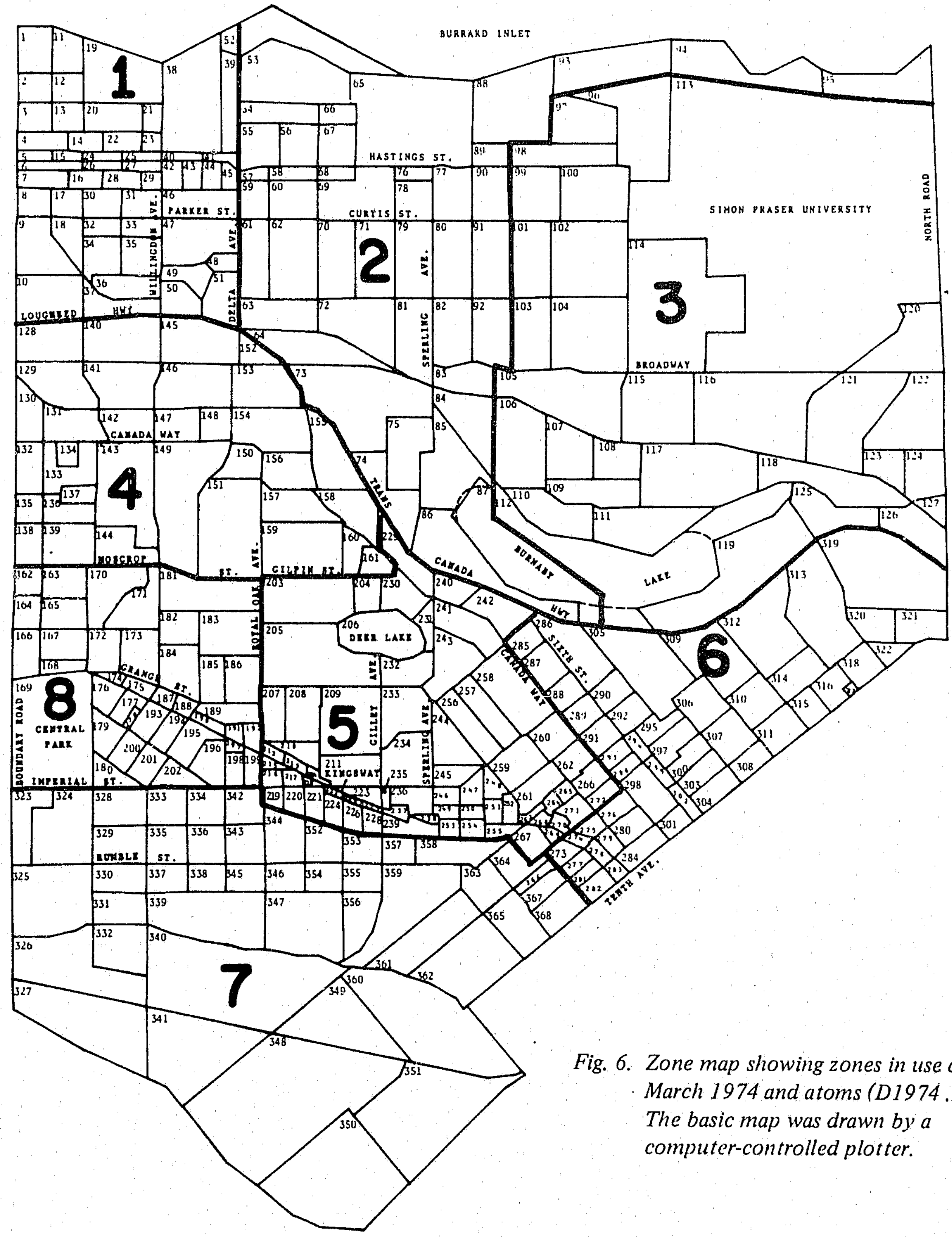

Fig. 6. Zone map showing zones in use during March 1974 and atoms (D1974 . 8). The basic map was drawn by a computer-controlled plotter.

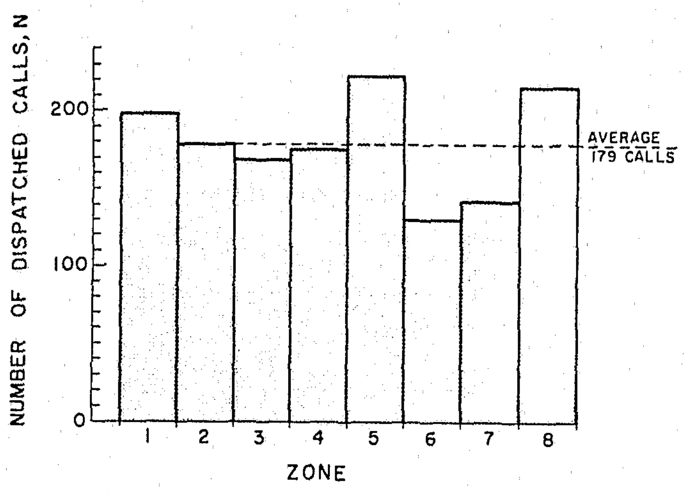

Fig. 7. Number of dispatched calls by zone for the experimental period.

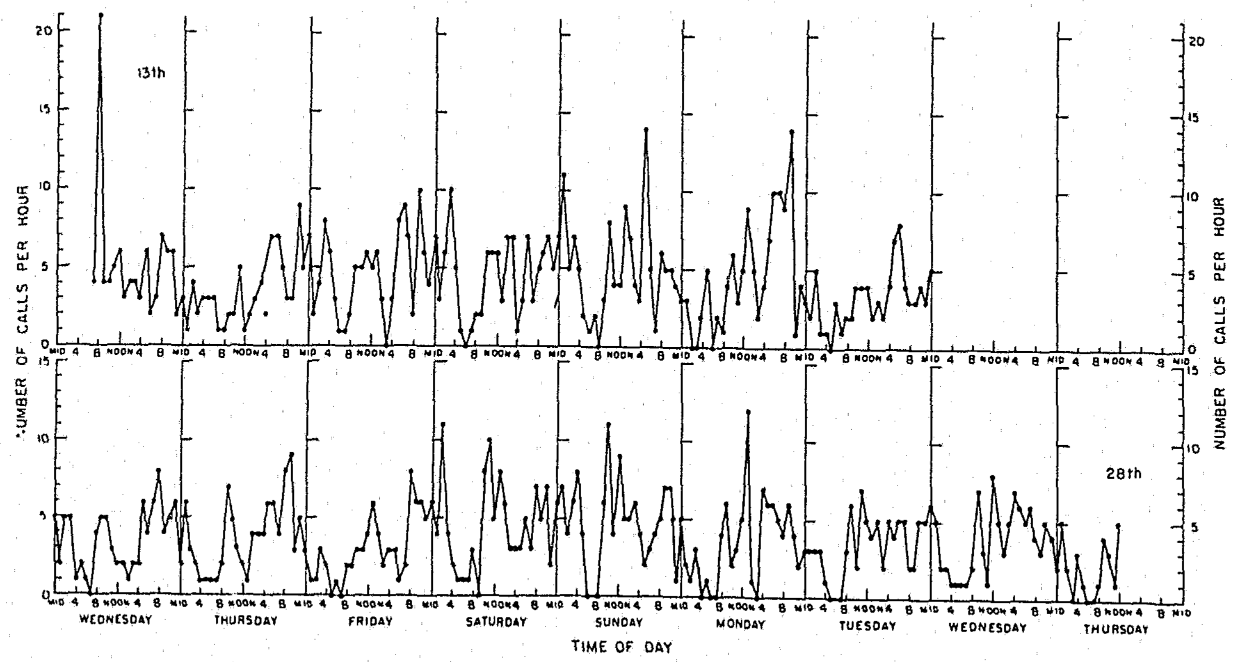

Fig. 8. Number of calls per hour to which a radio car was dispatched, by time of day, for 13–26 March 1974.

TABLE III. Number of calls per atom during the experimental period 13–26 March 1974.

Atom	No. of Calls	Atom	No. of Calls	Atom	No. of Calls	Atom	No. of Calls
1	1	51	3	101	4	151	0
2	4	52	0	102	0	152	3
3	3	53	7	103	7	153	0
4	0	54	10	104	0	154	7
5	0	55	4	105	1	155	7
6	11	56	4	106	4	156	1
7	2	57	1	107	1	157	4
8	2	58	1	108	3	158	4
9	2	59	0	109	5	159	2
10	4	60	5	110	0	160	3
11	1	61	2	111	3	161	4
12	0	62	7	112	1	162	3
13	0	63	6	113	18	163	5
14	0	64	5	114	0	164	2
15	0	65	6	115	9	165	2
16	4	66	3	116	7	166	2
17	1	67	3	117	6	167	3
18	0	68	5	118	13	168	2
19	6	69	4	119	0	169	13
20	6	70	3	120	1	170	4
21	2	71	4	121	11	171	4
22	1	72	5	122	10	172	2
23	3	73	1	123	14	173	1
24	3	74	5	124	33	174	0
25	1	75	2	125	3	175	3
26	23	76	2	126	3	176	13
27	8	77	8	127	6	177	7
28	6	78	1	128	2	178	0
29	1	79	3	129	2	179	1
30	6	80	11	130	5	180	9
31	8	81	4	131	3	181	2
32	3	82	3	132	5	182	6
33	2	83	1	133	8	183	1
34	4	84	11	134	2	184	5
35	2	85	7	135	3	185	1
36	0	86	3	136	4	186	2
37	3	87	0	137	4	187	7
38	5	88	13	138	1	188	0
39	3	89	2	139	5	189	7
40	3	90	3	140	17	190	1
41	3	91	3	141	0	191	4
42	11	92	7	142	3	192	0
43	7	93	0	143	3	193	13
44	1	94	2	144	5	194	10
45	3	95	2	145	16	195	17
46	12	96	0	146	4	196	5
47	5	97	0	147	2	197	4
48	2	98	2	148	0	198	5
49	1	99	2	149	10	199	8
50	18	100	1	150	0	200	19

TABLE III. (Cont'd)

Atom	No. of Calls	Atom	No. of Calls	Atom	No. of Calls	Atom	No. of Calls
201	10	251	2	301	9	351	0
202	15	252	8	302	2	352	4
203	5	253	0	303	4	353	3
204	2	254	2	304	3	354	6
205	3	255	13	305	1	355	0
206	0	256	4	306	3	356	5
207	2	257	3	307	2	357	2
208	1	258	4	308	1	358	1
209	3	259	4	309	0	359	5
210	3	260	1	310	0	360	7
211	6	261	5	311	2	361	3
212	0	262	5	312	1	362	4
213	0	263	0	313	3	363	1
214	1	264	1	314	2	364	6
215	9	265	0	315	0	365	4
216	0	266	4	316	3	366	1
217	2	267	3	317	0	367	4
218	1	268	8	318	2	368	2
219	2	269	6	319	5		
220	2	270	5	320	1		
221	4	271	4	321	2		
222	4	272	1	322	0		
223	2	273	2	323	5		
224	2	274	1	324	0		
225	4	275	3	325	5		
226	2	276	1	326	6		
227	2	277	9	327	0		
228	1	278	7	328	4		
229	2	279	6	329	0		
230	3	280	0	330	1		
231	0	281	1	331	4		
232	1	282	4	332	3		
233	0	283	6	333	3		
234	5	284	4	334	5		
235	1	285	0	335	1		
236	3	286	1	336	3		
237	12	287	1	337	2		
238	2	288	2	338	2		
239	13	289	4	339	3		
240	3	290	0	340	2		
241	6	291	4	341	0		
242	2	292	1	342	10		
243	3	293	7	343	3		
244	2	294	3	344	3		
245	2	295	2	345	7		
246	1	296	2	346	6		
247	4	297	2	347	3		
248	0	298	8	348	1		
249	2	299	3	349	1		
250	8	300	0	350	3		

TABLE IV. Number of calls per hour, 13–28 March 1975

DAY

HOUR	W 13	T 14	F 15	S 16	S 17	M 18	T 19	W 20	T 21	F 22	S 23	S 24	M 25	T 26	W 27	T 28
0-1		1	2	3	11	3	2	2	6	1	4	7	2	3	4	5
1-2		4	4	6	5	0	5	5	3	1	11	4	1	3	2	2
2-3		2	8	8	7	0	1	5	2	3	4	6	3	3	2	0
3-4		3	6	5	5	2	1	1	1	2	2	8	0	1	1	3
4-5		3	3	1	2	5	0	2	1	0	1	4	1	0	1	1
5-6		3	1	0	1	0	3	1	1	1	1	0	0	0	1	0
6-7	4	1	1	1	2	2	1	0	1	0	1	0	0	0	1	0
7-8	21	1	2	2	0	1	2	4	2	2	3	0	4	3	2	1
8-9	4	2	5	2	3	4	2	5	7	2	0	6	6	6	7	4
9-10	4	2	5	6	8	6	4	5	5	3	8	11	2	2	3	3
10-11	5	5	6	6	4	3	4	3	3	3	10	4	3	7	1	1
11-12	6	1	5	6	4	5	4	2	2	4	5	9	5	5	8	5
12-13	3	2	6	3	9	9	2	2	1	6	8	5	12	4	5	
13-14	4	3	3	7	7	5	3	1	4	4	6	5	1	5	3	
14-15	4	4	0	7	4	2	2	2	4	2	3	6	0	2	5	
15-16	3	2	3	1	3	4	4	2	4	3	3	4	7	5	7	
16-17	6	7	8	3	14	7	7	6	6	3	3	2	6	4	6	
17-18	2	7	9	7	5	10	8	4	6	1	5	3	6	5	5	
18-19	3	5	7	3	1	10	4	6	4	2	3	4	5	5	6	
19-20	7	3	2	5	6	9	3	8	8	8	7	5	4	2	4	
20-21	6	3	10	6	5	14	3	4	9	6	5	7	6	2	3	
21-22	6	9	6	7	5	1	4	5	3	6	7	7	4	5	5	
22-23	2	5	4	5	4	4	3	6	5	5	2	1	2	5	4	
23-24	3	7	7	7	3	3	5	2	3	6	6	5	3	6	2	

These data were averaged for 3-hour intervals for each day of the week with the results shown in Fig. 9. Here an approximately daily variation is shown, with a minimum of about 1.5 calls per hour around 4 o'clock in the morning, and a maximum of 5–8 calls per hour in late afternoon to early evening. On Friday and Saturday evening this maximum carries over to the following morning. Saturday and Sunday show a maximum around noon.

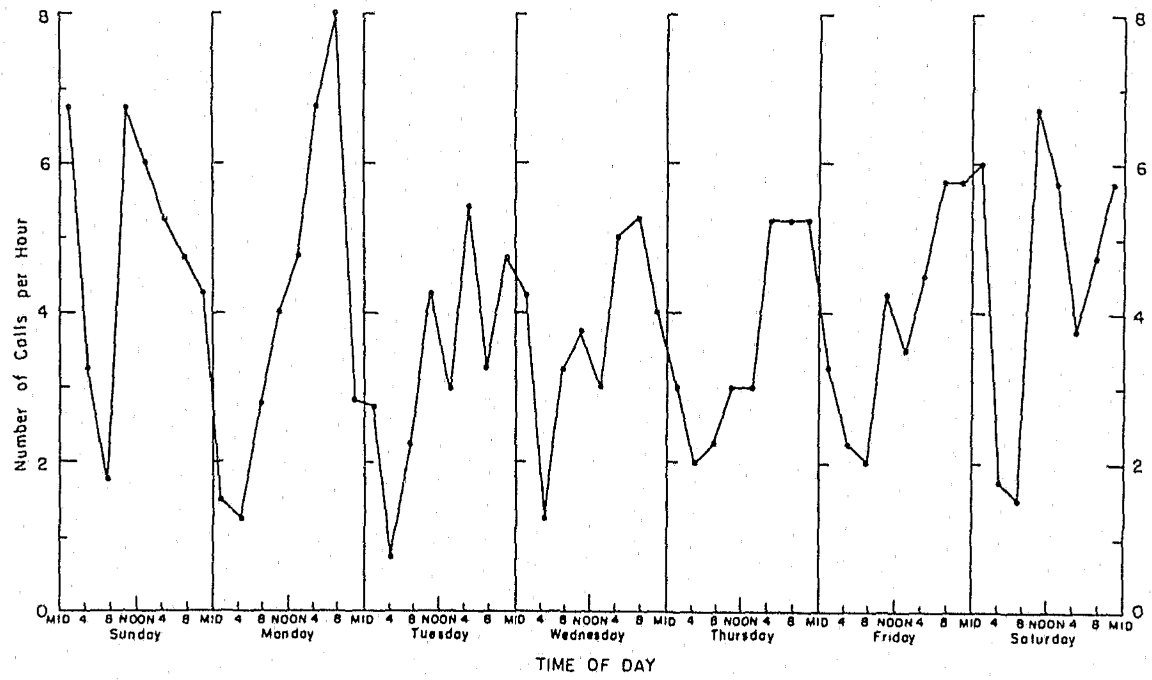

Fig. 9. Number of calls per hour to which a radio car was dispatched, by time of day, for 13–26 March 1974. In this diagram the calls have been averaged for three-hour intervals in order to emphasize daily variations.

The distribution of calls per hour is given Fig. 10, in which the experimental data are shown as a histogram, and a theoretical curve (known as a Poisson distribution) is fitted to the data. From the figure it will be seen that 4–5 calls per hour may be expected about 19% of the time; 5–6 may be expected 15% of the time; and so on. More than 12 calls per hour seldom occurred.

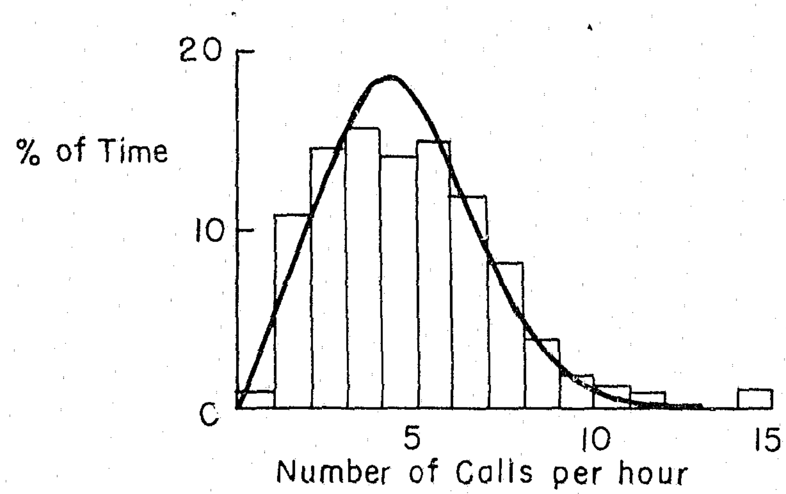

Fig. 10. Distribution of number of calls per hour as a percentage of time. The histogram shows experimental data to which a theoretical curve has been fitted. The equation for the curve is $\%T = N^a e^{-aN}/N!$ *where* $a = 4.637$.

The time taken from the receipt of a call for service to the dispatch of a car, or dispatch delay, is given in Table V and plotted in Fig. 11. The accuracy of the histogram is in doubt since it was found, after the data were taken, that the clock used for recording the time of receipt of a call and the clock used for recording the dispatch were not necessarily synchronized. On the other hand, the delays are comparable with those of other forces and should decrease with planned changes in the communications system. The curve fitted to the data is a negative exponential and is of the same form as that found for the Ottawa Police Force (4). The dispatch delay includes time necessary to effect transmission of details of the call, which was chosen as 3/4 minute for the prediction of response time, and time for a patrol car to become available. The latter may be expected to depend on the number of calls per hour. To verify this the data of Tables IV and V were averaged and plotted on a graph shown in Fig. 12. Although there is a large variation in the results, indicated by vertical bars, the dispatch delay clearly increases with the number of calls per hour.

Travel times (from dispatch to arrival at the scene) are shown as a histogram in Fig. 13. A Poisson distribution has been fitted to the data. The most probable travel time was 4.5 minutes.

Response times (dispatch delay plus travel time) were also determined. They are shown plotted in a histogram in Fig. 14. A theoretical curve (the sum of two exponentials) has been fitted to the data. The most likely response time is about 6 minutes, but there is a great variation, probably resulting from the large variation in dispatch delay.

TABLE V. Average dispatch delay (Minutes), 13 - 28 March 1975

HOUR	W 13	T 14	F 15	S 16	S 17	M 18	T 19	W 20	T 21	F 22	S 23	S 24	M 25	T 26	W 27	T 28
	DAY OF THE WEEK															
0-1	-	3	8.0	4.0	13.5	0.5	0.3	4.2	5.0	3.7	6.3	8.3	9.5	2.6	5.2	1.0
1-2	-	8.5	0	1.2	3.2	-	2.7	4.7	4.0	2.0	12.7	1.5	1.0	0	1.0	1.0
2-3	-	2	2.0	16.6	11.0	-	0	0.7	0	2.5	3.0	9.6	2.5	0	0	-
3-4	-	-	0	-	3.3	0	-	5.0	0	12.0	7.0	14.6	-	-	-	0
4-5	-	1	0	-	9.5	.7	0	4.5	0	-	3.5	12.0	0	-	-	0
5-6	-	2.5	1.0	-	8.0	-	2.0	1.0	0	1.0	-	-	-	-	-	-
6-7	1	-	-	2	-	.5	0	-	0	-	18.5	-	2	-	1.0	-
7-8	22.2	2	1.5	1.5	-	4.0	1.5	5.0	2.0	3.	5.5	-	2.7	-	0.3	0
8-9	8.3	23.6	25.6	2.0	5.5	5.7	2.0	5.6	3.6	16.5	-	3.4	2.2	8.0	13.0	27.0
9-10	7.7	7.0	2.0	10.3	6.8	5.0	5.0	5.3	2.4	17.8	7.6	9.3	0.0	0.6	11.0	7.3
10-11	2.3	7.3	4.2	2.5	12.3	0.5	2.5	-	11.0	7.0	11.9	3.4	11.3	4.3	3.3	2.0
11-12	14.0	-	1.5	6.2	8.5	1.0	1.7	8.0	8.5	0.7	6.0	4.8	7.4	12.3	2.6	4.4
12-13	-	-	5.6	3.8	6.8	6.0	0.5	-	7.0	21.4	9.9	10.6	7.7	8.0	39.8	
13-14	11.2	16.5	2.0	16.5	15.8	1.5	7.0	2.5	12.0	13.2	11.7	1.5	1.0	42.0	6.0	
14-15	36.0	2.0	1.0	16.3	5.5	2.0	7.5	2.0	6.5	-	34.5	1.2	-	19.0	6.0	
15-16	4.0	2.2	5.7	2.0	4.6	9.0	0.7	2.0	11.0	2.5	3.0	19	7.4	4.2	8.8	
16-17	9.0	1.6	2.8	9.0	16.5	8.3	0.7	1.7	9.2	0	18.6	0.6	5.7	11.0	12.3	
17-18	1	9.6	9.5	2.0	23.3	13.2	24.0	9.5	4.7	3.0	5.2	0.0	18.6	2.4	9.0	
18-19	1	4.0	3.8	1.7	2.0	5.4	23.2	6.3	10.0	1.0	9.5	1.7	0.6	9.5	9.0	
19-20	15.4	1.5	4.3	3.0	5.7	12.3	11.0	18.6	13.7	1.8	10.1	0.3	12.0	4.0	2.5	
20-21	5.	2.6	6.9	3.5	10.5	14.8	20.6	12.5	4.6	6.7	6.5	15.5	4.0	23.0	1.7	
21-22	0.6	4.2	0.5	11.7	-	0	4.0	4.8	11.3	1.8	11.8	13.0	4.5	16.7	9.4	
22-23	2.5	3.6	2.0	7.8	6.3	14.2	6.7	39.0	3.2	1.5	10.0	16.5	-	21.3	19.5	
23-24	3.5	8.4	13.0	7.5	4.5	-	2.0	0.0	1.0	7.5	3.0	2.2	1.0	7.2	1.0	

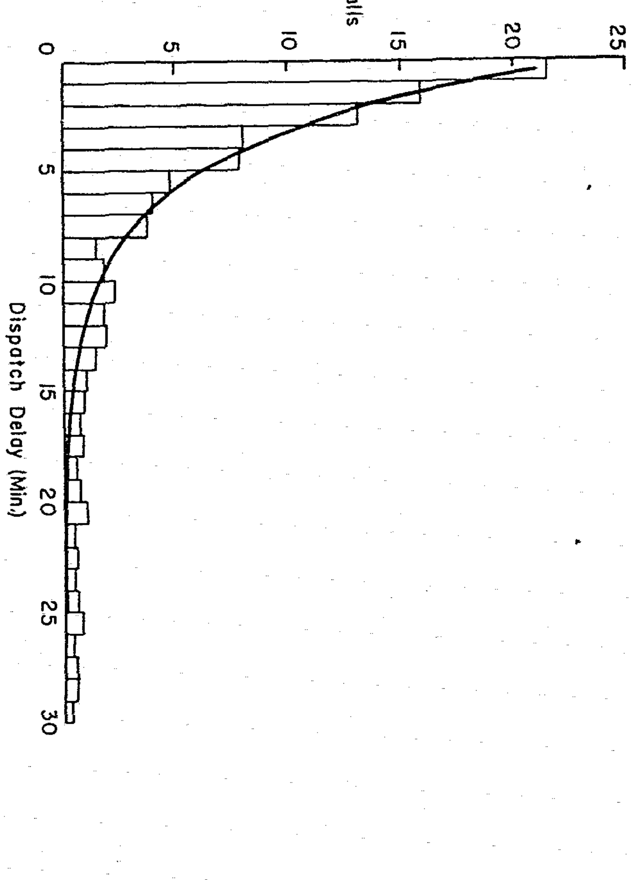

Fig. 11. Dispatch delay, D, or time taken from receipt of a call for service to dispatch of a car, including waiting time (or queuing time). The longest delays are for calls to which dispatch was postponed. A negative exponential has been fitted to the data, with the equation %C = 24.1 exp (-0.265 D).

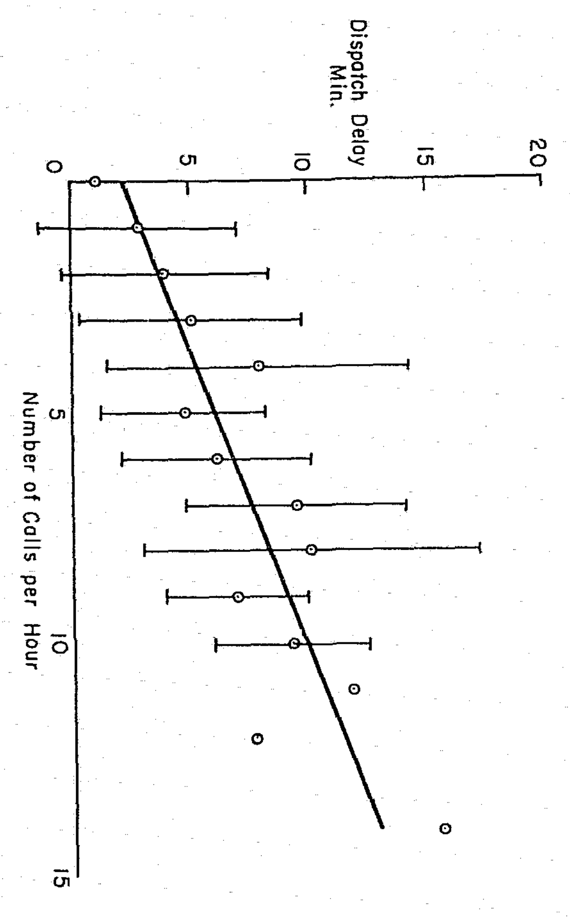

Fig. 12. Dispatch delay, D, as a function of number of calls per hour, N. The data of Tables IV and V were used to determine the average dispatch delay indicated by small circles. Where enough data were available the standard deviation was calculated, and is indicated by vertical bars. A straight line was fitted to the average values of D with the equation D = 2.20+0.78 N.

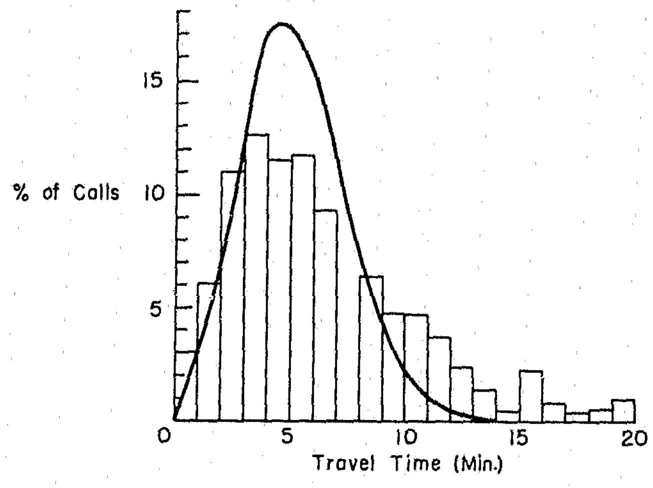

Fig. 13. Travel time, T, or time taken from dispatch of a car to arrival at the scene of the call. Experimental data are shown as a histogram, to which a Poisson distribution has been fitted, with the equation $\%C = T^a e^{-a} T / T!$ where a = 5.22.

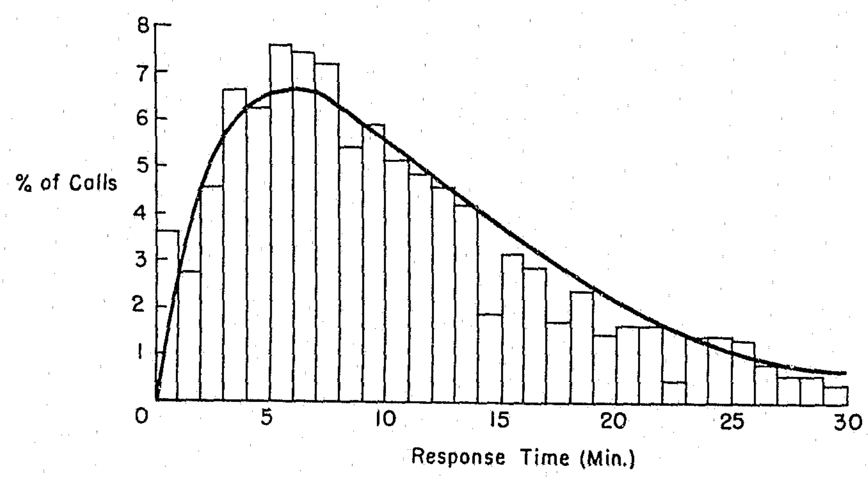

Fig. 14. Response time, R, or time taken from receipt of a call to arrival at the scene. In principle response time is the sum of dispatch delay plus travel time. The curve fitted to the experimental data shown in the histogram is a sum of exponentials, with the equation $\%C = a \exp(bR)(1 - \exp -bR)$ with a = 0.264 and b = 0.115.

Service times (from arrival at the scene to return to patrol) are shown in Fig. 15. As before the data are shown as a histogram and a curve has been fitted, in this case a negative exponential.

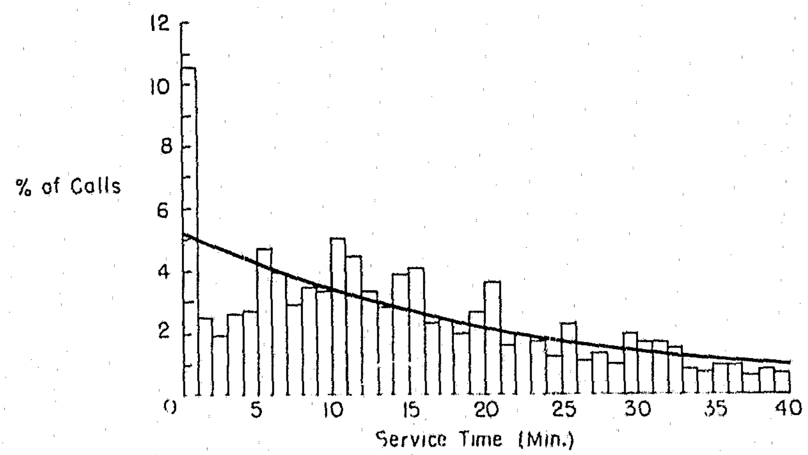

Fig. 15. Service time, S, or time spent at the scene of the call A negative exponential has been fitted to the data, with the equation $\%C = 5.17 \exp(-0.425\ S)$.

The curves fitted to the travel times, response times, and service times are of the same form as those for the Ottawa Police Force (4).

Division into Atoms

During the data taking period, a large map of Burnaby was divided into atoms with the assistance of experienced officers. A master atom map was drawn, digitized and later redrawn on a convenient scale using a computer-controlled plotter for use in recording data and in arranging zones as shown in Fig. 6. Another version of the atom map was prepared by drawing atom boundaries and numbers on a map published by the Burnaby Planning Department. A section of this map is shown in Fig. 16. It was photographed in a copying camera to give an 8 x 10 inch negative, and from this negative two enlargements approximately 22 x 30 inches and 40 x 54 inches were produced on Kodagraph film. The enlargements may be used to produce inexpensive Ozalid prints for keeping records and planning.

Computer Summary of Data

The data on all calls were keypunched and run through a program which summarized all types of occurrences atom by atom for the experimental period. A portion of the computer printout is given in Fig. 17. Such a table can be produced periodically for management purposes if the data are regularly keypunched.

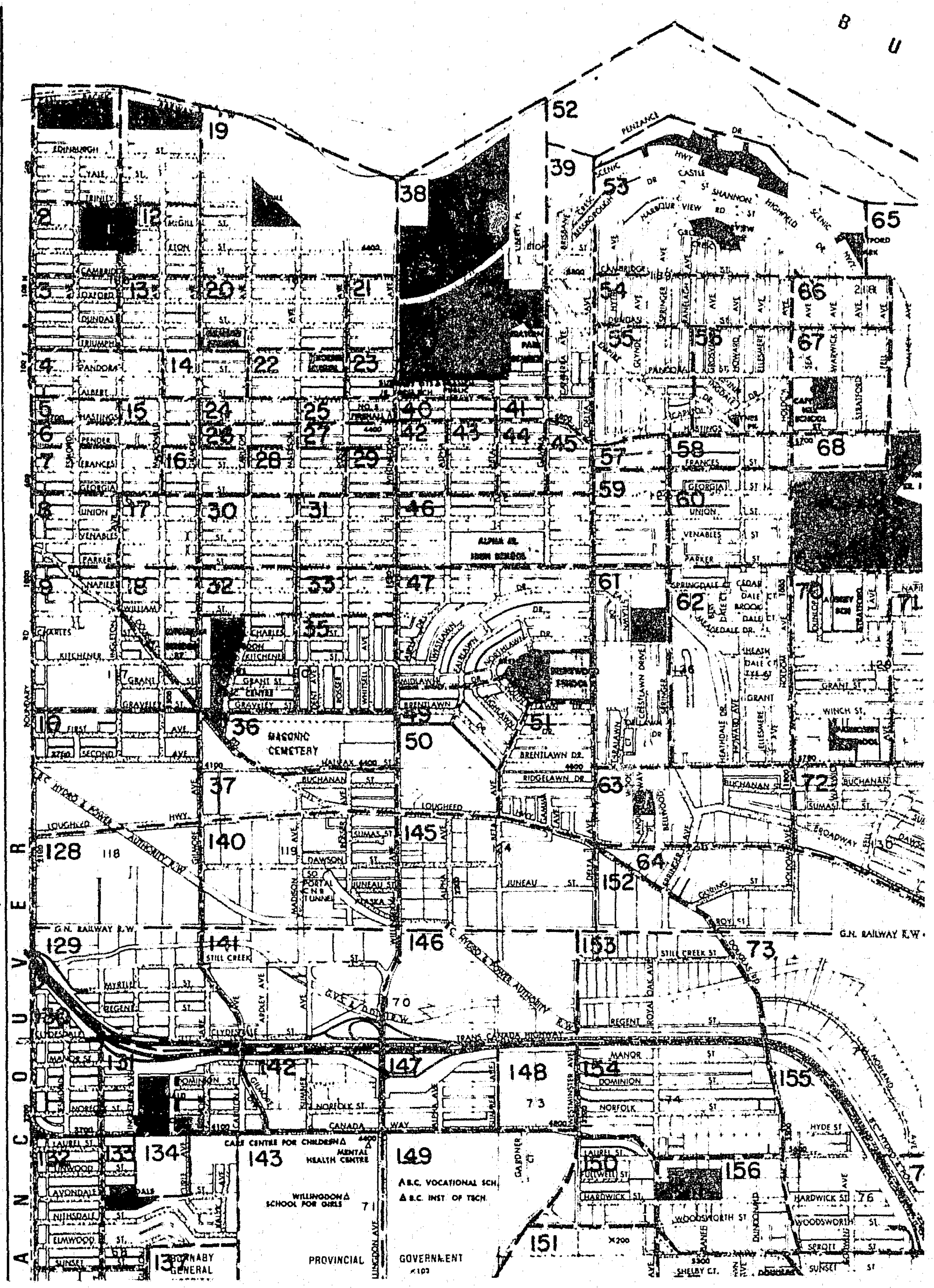

Fig. 16. Portion of the Burnaby atom map

TYPE OF OCCURRENCE (DISPATCHER-OFFICER CLASSIFICATION)

ATOM	676	677	678	679	680	681	682	683	684	685	686	687	688	689	690	691	692	693	694	695	696	697	698	699	700
350	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	3
351	C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
352	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	4
353	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
354	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
355	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
356	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
357	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
358	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
359	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	5
360	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7
361	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
362	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
363	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
364	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
365	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	4
366	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
367	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
368	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
369	98	4	14	1	2	2	1	1	0	1	1	11	0	2	18	40	13	11	1	0	9	31	139	0	1431

TOTAL OCCURRENCES FOR EACH ATOM

TOTAL OF EACH TYPE OF OCCURRENCE

TOTAL NO. OF CALLS

Fig. 17. Portion of a computer printout giving a tabulation of all occurrences for the experimental period. The occurrence types are given in Table I.

III. DATA USED FOR SIMULATIONS

Input Data

The average number of calls per hour, N, average time between calls, ΔT, and length of simulation are given in Table VI. The length of the simulations was chosen so that approximately 400 calls, a good number for statistical purposes, would be received. For example with $\Delta T = 32$ and $N = 60/32 = 1.875$ one would expect 400 calls in $400/1.875 = 213.3$ hours, the time chosen. The computer used only a fraction of the simulation time (about 2 minutes) for the calculations. Other input data and strategies are given in Table VII.

TABLE VI. Number of calls per hour and length of simulation

Number of calls per hour, N	*Average time between calls, ΔT, minutes*			*Length of simulation hours*
	Average	*Maximum*	*Minimum*	
1.875	32	160	3	213.3
3.75	16	80	1	106.6
7.5	8	40	0	53.25
15	4	20	0	26.6
30	2	10	0	13.25
60	1	5	0	6.6

TABLE VII. Input data and strategies for simulations

Number of atoms	368
Number of zones	
Number of patrol cars	
Number of priorities	3
Abbreviations	P1,P2, P3
Priority Distribution (based on analysis of calls for service)	P1 - 15% of all calls P2 - 45% of all calls P3 - 40% of all calls

Preemption rules and distances:

A car may be preempted from a call, reassigned to a queued call or assigned from patrol if the priority of the arriving call is high enough and if the car is within a certain distance of the call. The distances for the three priorities are as follows:

	Type of Dispatch		
Priority	*Preemption*	*Reassignment*	*Assignment*
P1	4.0 miles	4.0 miles	4.0 miles
P2	4.0 miles	3.0 miles	4.0 miles
P3	4.0 miles	2.0 miles	4.0 miles

Service time per call, excluding travel time, minutes

Priority	*Average*	*Maximum*	*Minimum*
P1	5	25	0
P2	10	50	0
P3	15	75	1

Types of strategy used in assigning cars :

1A. Municipality assignment (D)
1B. District assignment (for 6 zone arrangements) (D)
2. Zone assignment (Z)

Types of strategy used in assigning queued calls:

1. Closest waiting call (CWC)
2. First come first served (FCFS)

Relative rate of calls - calculated from Table III.
Average speed of car - 22.0 mph for all priorities.

Zones

Four basic arrangements of zones were used. The first, shown in Fig.6, included 8 zones as used by the force during the data-taking period of March 1974 and is labeled D1974. These zones were used with 1, 2 or 3 cars per zone.

The next set of zones, shown in Fig. 18, included 4 zones labeled JNO4Z1 and were used with 1, 2, or 4 cars per zone.

The next set of zones, shown in Fig. 19, divided the municipality into six zones labeled AD6Z1. These zones could in turn be divided into two sets of two districts. In the first pair of districts, called AD6Z2A, zones 1, 2, and 3 were combined to form District 1 and zones 4, 5, and 6 were combined to form District 2. In the second pair of districts, called AD6Z2B, zones 1, 5, and 6 were combined to form District 1 while zones 2, 3, and 4 were combined to form District 2. In the AD6Z2A and AD6Z2B zones dispatch could either be confined within a zone (Z) or confined to a district (D). Each zone was patrolled by 1, 2, or 3 cars.

The final set of zones, shown in Fig. 20, included 8 zones with nearly equal workloads labeled FL8Z1. They were used with 1, 2, or 3 cars per zone.

Set of Simulations

Simulations were run with different combinations of variable as follows:

Number of calls per hour - 1.875; 3.75; 7.5; 15; 30; 60
Assignment and reassignment strategies* - DCWC; DFCFS; ZCWC; ZFCFS
Types of zones - JNO4Z1; AD6Z1; AD6Z2A; AD6Z2B; D1974; FL8Z1
Total number of cars - 4, 6, 8, 12, 16, 18, 24.

A total of 324 simulations were made, as illustrated in Table VIII.

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* D - district dispatch, in which a car may be dispatched out of its zone to another if no car is available in the second zone.

Z - zone dispatch, in which a car may be dispatched only to calls within its own zone.

CWC - closest waiting call reassignment, in which a car completing a call is reassigned to the closest waiting call (if any) in queue.

FCFS - first come first served reassignment, in which a car completing a call is reassigned to the first call (if any) in queue.

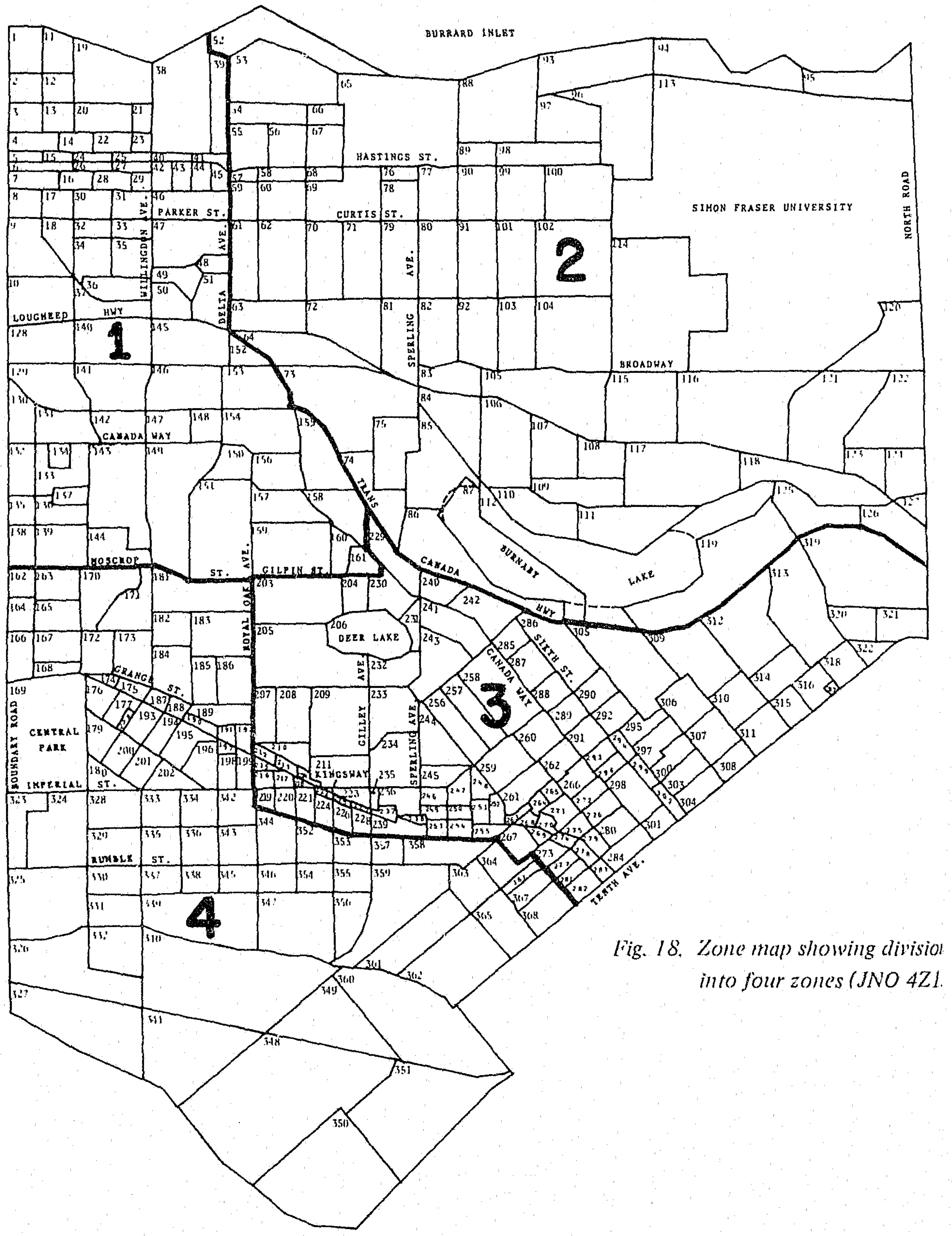


Fig. 18. Zone map showing divisio[n] into four zones (JNO 4Z1.

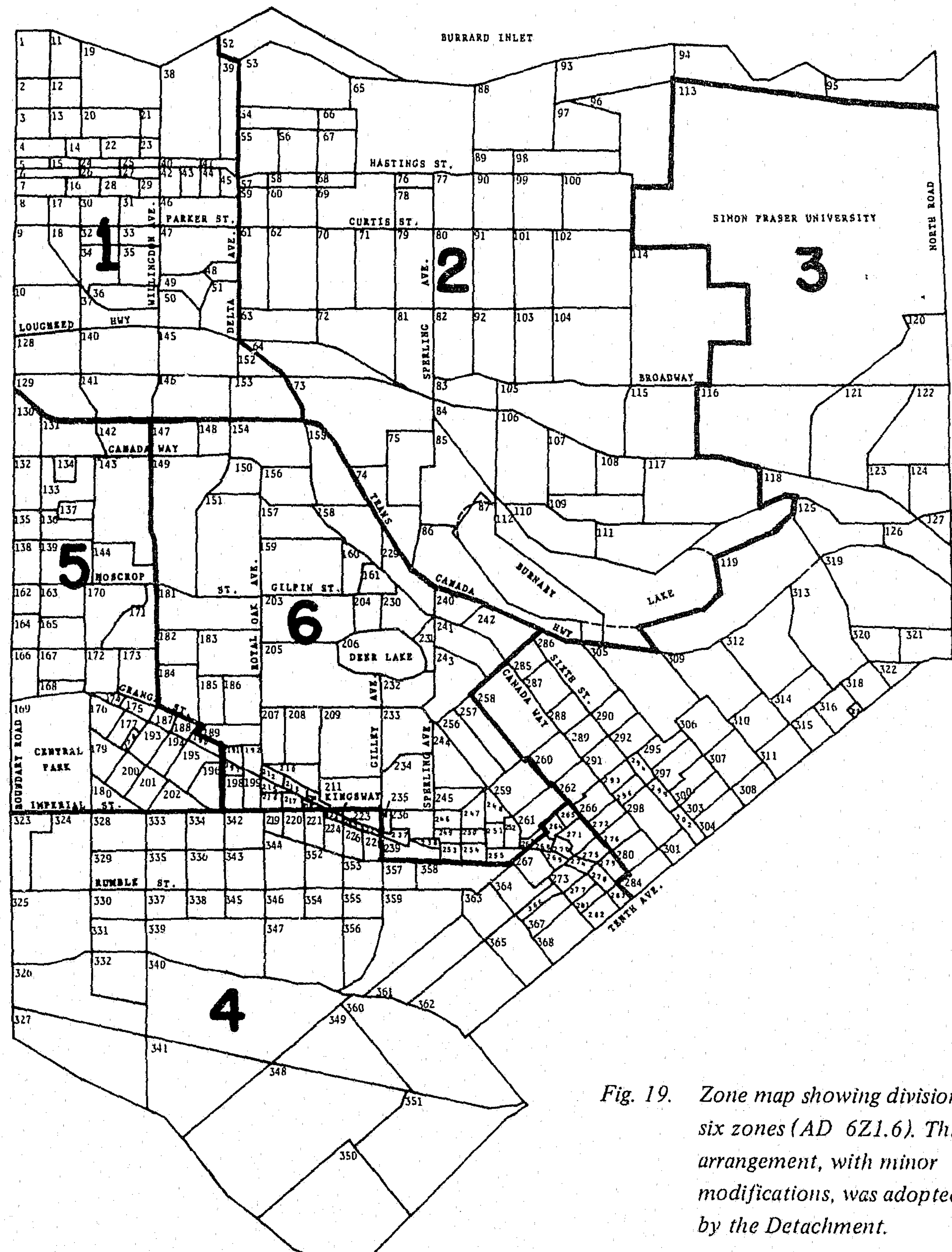


Fig. 19. Zone map showing division into six zones (AD 6Z1.6). This arrangement, with minor modifications, was adopted by the Detachment.

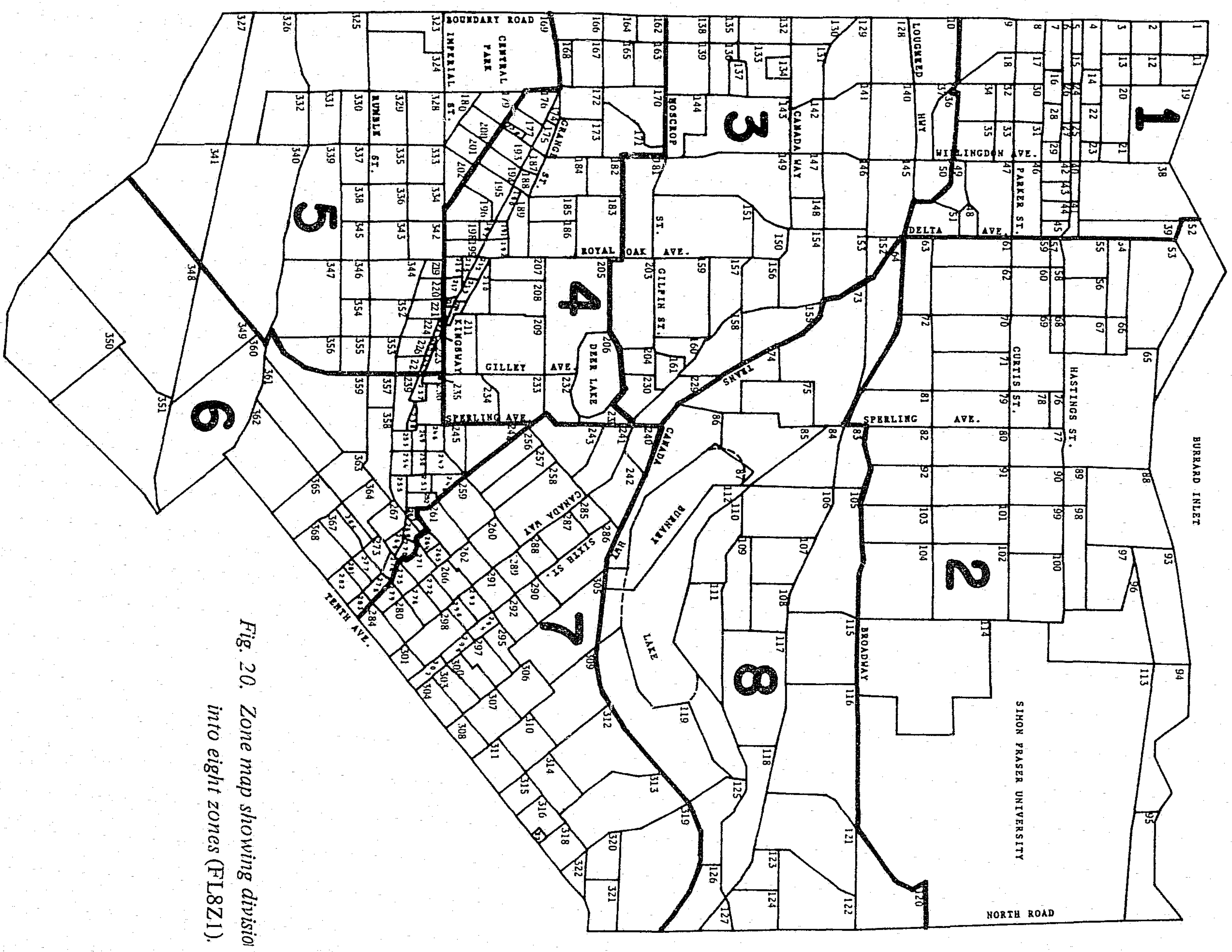


Fig. 20. Zone map showing divisio into eight zones (FL8Z1).

TABLE VIII. Average number of calls in queue during simulation. Blank spaces indicate zero calls in queue. Spaces marked S indicate saturation, or 100 calls in queue within a few hours of simulated operations.

Zones and Number of Cars	Average Number of Calls per Hour, N, and Strategy																	
	1.875		3.75				7.5		15				30		60			
	DCWC	ZCWC	DCWC	DFCFS	ZCWC	ZFCFS	DCWC	ZCWC	DCWC	DFCFS	ZCWC	ZFCFS	DCWC	ZCWC	DCWC	DFCFS	ZCWC	ZFCFS
JNO.4Z1.4								.1	3.8	5.2	3.2	1.9	S	S	S	S	S	S
AD.6Z1.6		.2			.7	.7		.5	.2	.2	.6	1.0	7.2	6.8	S	S	S	S
AD.6Z2A.6		.2			.7	.7	.1	.5	.3	.6	.6	1.0	6.3	6.8	S	S	S	S
AD.6Z2B.6		.2			.7	.7		.5	.2	.2	.6	1.0	6.1	6.8	S	S	S	S
D1974.8											.4	.3	1.4	1.5	S	S	S	S
FL8Z1.8											.1	.2	1.5	2.6	S	S	S	S
JNO.4Z1.8											.1	.2	1.5	3.5	S	S	S	S
AD.6Z1.12													.1	.3	5.9	6.4	6.2	6.1
AD.6Z2A.12													.1	.3	5.2	5.0	6.2	6.1
AD.6Z2B.12													.2	.3	4.7	4.8	6.2	6.1
D1974.16										.1		.1		.3	.8	1.8	2.9	2.9
FL8Z1.16													.1	.1	.4	.9	2.0	1.6
JNO.4Z1.16													.1	.2	2.2	1.7	1.7	2.3
AD.6Z1.18														.1	.1	.4	1.5	2.1
AD.6Z2A.18									.3				.02	.1	1.0	.9	1.5	2.1
AD.6Z2B.18														.1	1.0	.5	1.5	2.1
D1974.24															.1	.1	.7	.4
FL8Z1.24																	.3	.6

Computer Programs

The computer programs were written for Fortran IV and run on the National Research Council's time sharing computer (IBM 360 Model 67). The simulation programs were those used for Gloucester (2) with minor modifications. Four areas of programming were involved in the project: plotting, data analysis, data preparation and simulation.

The atom maps were digitized and plotted on scales ranging from 8 1/2" x 11" to 36" x 36". The former were used for zone maps (Figs. 18–20) while the latter were used in redesigning zones by considering percentage rates of calls assigned to each atom.

In the analysis of the data there were approximately 1500 data cards. Three programs were written for the analysis. The first sorted the occurrences atom by atom. (It will be recalled that Burnaby was divided into 368 atoms and 100 different types of occurrences were listed (Table I and Fig. 17)). The second program was a statistical routine that grouped data such as communication center delay time, travel time, and service times by shift and by day, including calculations of means and standard deviations (Figs. 11–15). The third program was used on the grouped data to produce the various fitted curves. A least squares, nonlinear regression package called MARQRT (Marquardt) was used for this purpose (5).

The data preparation was the most exacting part of the study. Since the data base included only two weeks of data during March 1974 it was found that certain atoms had no occurrences. In the program this would always result in no calls to this atom. It was therefore decided to add one occurrence to each atom. Work maps were prepared with the adjusted rates and the data base was calculated as described in the following example. Zone 1 included 51 atoms and received 198 calls for service during the experimental period, which was 13.84% of the total calls. These calls were adjusted as shown in Table IX and the resulting value was used to calculate the zone normalization factor, ZNF, from the formula $ZNF = \%\ calls/\Sigma(ANC \times NA) = 13.84/249 = 0.0556$. The percentage rates of calls were then calculated. The results for Zone 1 are shown in Fig. 21.

The simulation requires a three-priority distribution for each atom. For the present work the occurrences (Table I) were divided into three priorities and the percentage of occurrences of each priority was calculated. They were 15% priority one, 45% priority two and 40% priority three.

In contrast to the Gloucester study (2) it was decided to calculate the center of mass (centroid) for each atom and to use it as input data. This was done to reduce computer time since there were more than three times as many atoms in Burnaby as in Gloucester. Up to three cars per zone were used in Burnaby while in Gloucester only one was used.

All 324 simulations were done in one day during a weekend when the computer was lightly loaded. Nine hours of central processing unit time were used. This was cheap and fast. Three input data sets were used in each simulation run. The first was the basic

TABLE IX. Calculation of zone normalization factor, ZNF, and percentage rates of calls for Zone 1, Fig. 6.

No. of calls N	Adjusted No. of calls ANC	No. of atoms NA	Product (ANC)NA	Percentage Rate of calls (ANC) (ZNF)
0	1	8	8	0.0556
1	2	8	16	0.1112
2	3	8	24	0.1668
3	4	9	36	0.2224
4	5	4	20	0.2780
5	6	3	18	0.3336
6	7	3	21	0.3892
7	8	1	8	0.4448
8	9	2	18	0.5004
11	12	2	24	0.6672
12	13	1	13	0.7228
18	19	1	19	0.0564
23	24	1	24	1.3344
		51	249	

ZNF = 13.84/249 = 0.0556

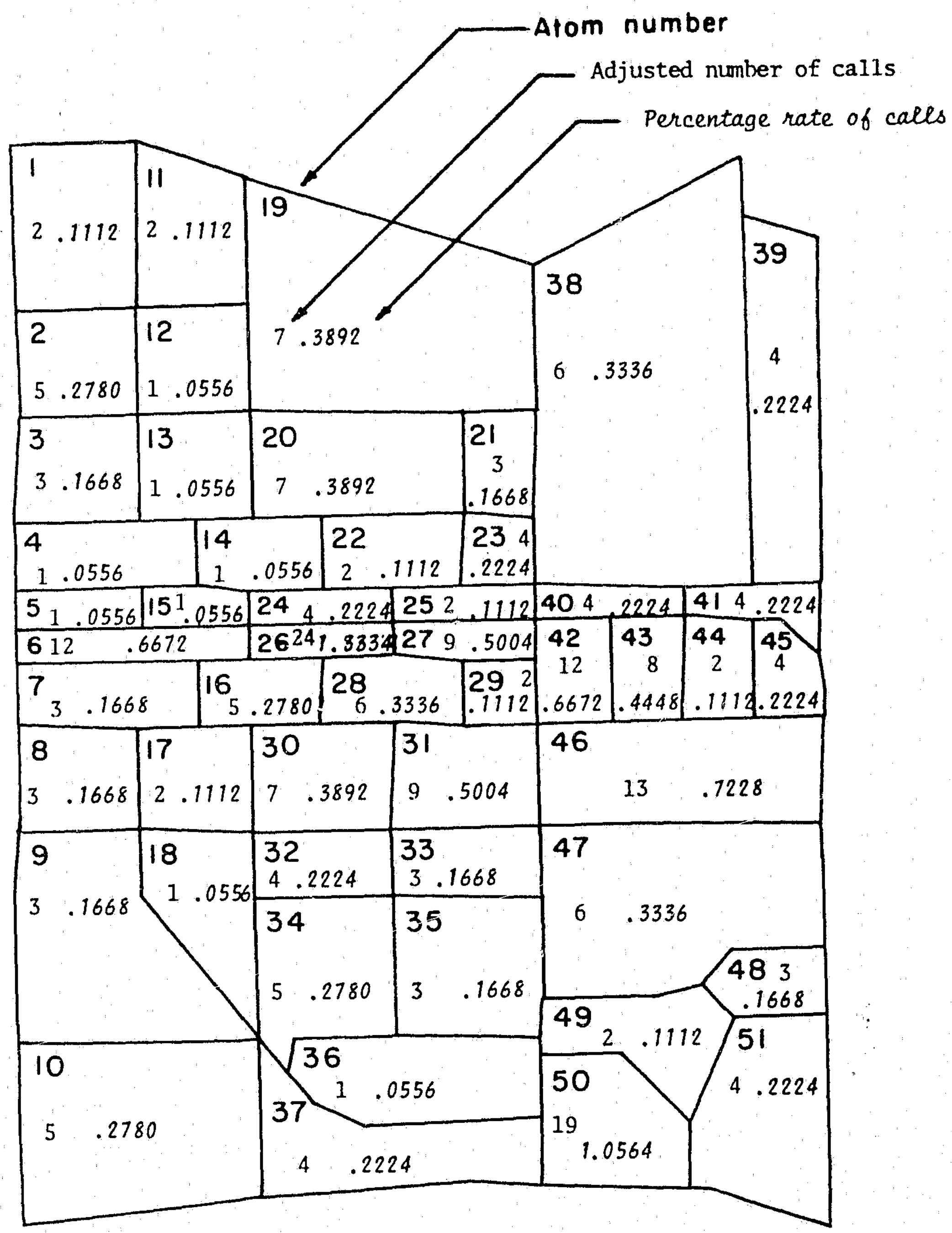


Fig. 21. Atom map of Zone 1, D1974 (Fig. 6) showing atom number, adjusted number of calls and percentage rate of calls as calculated in Table VIII.

geographical information, the second the zone configurations for the run and the third contained the rate of calls and strategies (Table VII). There were one geographical, 18 zone, and 18 rate datasets for a total of 37. The three datasets required 16, 4, and 1 pages respectively of storage (4096 bytes/page).

The simulation package contained the main program along with 15 subroutines. It required 73 pages of storage. (Source deck contains approximately 2000 cards.) The average simulation took approximately two minutes of central processing unit time.

Output Data

Each computer printout included the initial positions of the cars and final statistics. For some simulations call-by-call details were printed. An example is given in Fig. 22. They included the following:

- Time, number and priority of call
- Location of call - zone, atom, x- and y-coordinates
- Identity of car sent
- Travel time and service time
- Status for force - No. of cars on patrol
  - No. of cars on call
- Number of calls in queue - P1, P2 and P3
- Remarks

The final statistics included the following:

- Duration of simulation until number of calls in queue reached 100, if applicable (saturation)
- Number of calls being serviced at the end of the simulation
- Number of calls in P1 queue at the end of the simulation
- Number of calls in P2 queue at the end of the simulation
- Number of calls in P3 queue at the end of the simulation
- Number of P2 calls preempted
- Number of P3 calls preempted
- Number of hours used to travel to calls
- Number of hours used to service calls
- Number of car hours in the simulation
- Percentage of time available for preventive patrol
- Hours of preventive patrol time available per 8 hour shift
- Percentage of calls placed in queue
- Number of calls placed in queue
- Maximum number of calls in queue simultaneously
- Maximum number of cars simultaneously on call
- Average service time, with standard deviation and distribution by zone and priority
- Workload (number of calls per 8 hour shift) by priority and car, with histogram
- Average travel time, with standard deviation and distribution, by zone.
- Average number of calls in queue, with standard deviation and distribution, by zone and priority
- Number and percentage of calls per car, all priorities, with histogram
- Response time by car, all priorities

An example of a table and histogram printed out by the computer are given in Fig. 23.

```
INITIAL POSITIONS OF PATROL CARS

CAR   STATUS    X       Y
NO.           MILES   MILES
101    P      0.893   7.558
102    P      1.350   5.723
201    P      2.188   4.724
202    P      3.070   5.847
301    P      5.359   6.544
302    P      4.089   2.918
401    P      0.020   2.129
402    P      3.685   2.512
501    P      0.427   4.408
502    P      0.668   2.928
601    P      0.968   4.883
602    P      2.939   3.099

TIME  CALL  CALL  PRIO  LOCATION OF CALL        CAR  MINS TO  SERV  STATUS OF VEHICLES  CALLS IN   REMARKS
HOURS NO.   TYPE  RITY  ZONE  ATOM   X     Y    NO.  REACH    TIME  PATROL   ON CALL    QUEUE
                                                                                       P1 P2 P3
                                                            11       1        0  0  0  CAR SENT
0.01   1     2     1    302   308  4.63  3.04  302  1.82          10       2        0  0  0  CAR SENT
0.03   2     2     3    401   342  1.62  2.79  401  4.53                                   OUTSIDE CARS AREA
                                  295               602                                     CAR SENT
0.06   3     2     3    202   295  4.12  3.29  602  3.74           9       3        0  0  0  CAR SENT
0.09   4     2     2    101    27  0.82  6.95  101  1.86           8       4        0  0  0  OUTSIDE CARS AREA
                                  186               502                                     CAR SENT
0.10   5     2     3    601   186  1.42  3.63  502  3.97           7       5        0  0  0  CALL ENDED
0.10   1                                            302       3.8                           CAR ON PATROL
0.10              202                4.45  2.82  302  2.43           8       4        0  0  0  CAR SENT
0.12   6     2     2    301   118  5.41  4.74  301  5.06           7       5        0  0  0  CAR SENT
0.14   7     2     3    201    81  2.70  6.02  201  4.39           6       6        0  0  0  CALL ENDED
0.22   2                                            401       6.6                           CAR ON PATROL
0.22                    401        1.34  2.37  401  4.21           7       5        0  0  0  PRE-EMPTION
0.09   4           2    101    27  0.82  6.95                                      0  1  0  CAR SENT
0.22   8     2     1    101    28  0.82  6.83  101  0.33           7       5        0  1  0  CAR SENT
0.23   9     2     2    401   133  0.75  2.01  401  2.34           6       6        0  1  0  OUTSIDE CARS AREA
                                   15               102                                     CAR SENT
0.25  10     2     3    101    15  0.45  7.02  102  6.00           5       7        0  1  0  OUTSIDE CARS AREA
                                  198               601                                     CAR SENT
0.26  11     2     3    602   198  1.48  2.90  601  6.80           4       8        0  1  0  PRE-EMPTION
0.10   5           3    502   186  1.42  3.63                                      0  1  1  CAR SENT
0.27  12     2     2    502   187  1.04  3.49  502  1.42           4       8        0  1  1  OUTSIDE CARS AREA
                                  270               302                                     CAR SENT
0.28  13     2     2    402   270  3.52  2.70  302  2.07           3       9        0  1  1  CAR SENT
0.29  14     2     3    402   372  0.89  1.82  402  9.50           2      10        0  1  1  OUTSIDE CARS AREA
                                   67               202                                     CAR SENT
0.32  15     2     3    201    67  2.00  6.95  202  5.91           1      11        0  1  1  CAR SENT
0.33  16     2     3    501   135  0.19  4.61  501  1.19           0      12        0  1  1  OUTSIDE CARS AREA
                                   76               202                                     PRE-EMPTION
0.32  15           3    201    67  2.00  6.95                                      0  1  2  CAR SENT
0.37  17           2    201    76  2.58  6.92  202  1.66           0      12        0  1  2  CALL ENDED
0.37   7                                            201       9.4                           QUEUE SERVICED
0.37  15     2     3    201    67  2.00  6.95  201  4.42           0      12        0  1  1  CALL ENTERS QUEUE
0.37  18     2     3    501   168  0.34  3.67                                      0  1  2  PRE-EMPTION
0.27  12           2    502   187  1.04  3.49                                      0  2  2  CAR SENT
0.38  19     2     1    502   176  0.66  3.42  502  1.22           0      12        0  2  2  CALL ENDED
0.38   8                                            101       9.4                           QUEUE SERVICED
0.38   4     2     2    101    27  0.82  6.99  101  0.37           0      12        0  1  2  CALL ENDED
0.40   9                                            401       7.5                           QUEUE SERVICED
0.40  12     2     2    502   187  1.04  3.49  401  2.14           0      12        0  0  2  CALL ENDED
0.41  19                                            502       0.5                           QUEUE SERVICED
0.41  18     2     3    501   168  0.34  3.67  502  1.55           0      12        0  0  1  CALL ENTERS QUEUE
0.41  20     2     3    602   209  2.30  3.44                                      0  0  2  CALL ENDED
0.41   3                                            602      17.8                           QUEUE SERVICED
0.41  20     2     3    602   209  2.30  3.44  602  5.36           0      12        0  0  1  CALL ENDED
0.41   9                                            101       1.5                           CAR ON PATROL
0.41                    101        0.55  5.95  101  7.59           1      11        0  0  1  CALL ENDED
0.41   6                                            301      12.7                           CAR ON PATROL
0.41                    301        5.45  5.81  301  6.68           2      10        0  0  1  CALL ENDED
0.43  10                                            102       5.2                           CAR ON PATROL
0.43                    102        0.85  5.48  102 11.71           3       9        0  0  1  QUEUE SERVICED
0.43   5     2     3    601   186  1.42  3.63  102  6.56           2      10        0  0  0  OUTSIDE CARS AREA
                                  184               101                                     CAR SENT
0.45  21     2     3    601   184  1.03  3.80  101  7.19           1      11        0  0  0  CALL ENTERS QUEUE
0.46  22     2     3    601   184  1.10  3.72                                      0  0  1  OUTSIDE CARS AREA
                                  277               602                                     PRE-EMPTION
0.41  20           3    402   209  2.30  3.44                                      0  0  2  CAR SENT
0.47  23     2     2    402   277  3.59  2.37  602  6.41           1      11        0  0  2  CALL ENDED
0.47  16                                            501       7.5                           QUEUE SERVICED
0.47  22     2     3    601   184  1.10  3.72  501  4.91           1      11        0  0  1  OUTSIDE CARS AREA
                                   85               301                                     CAR SENT
0.49  24     2     3    201    85  2.72  4.72  301 10.40           0      12        0  0  1  CALL ENTERS QUEUE
0.49  25     2     3    101    31  0.74  6.74                                      0  0  2  CALL ENDED
0.49  11                                            601       7.4                           QUEUE SERVICED
0.49  20     2     3    302   209  2.30  3.44  601  3.73           0      12        0  0  1  OUTSIDE CARS AREA
                                  112               301                                     PRE-EMPTION
0.49  24           3    202    85  2.72  4.72                                      0  0  2  CAR SENT
0.50  26     2     2    202   112  4.12  4.30  301  4.96           0      12        0  0  2  OUTSIDE CARS AREA
                                  170               101                                     PRE-EMPTION
0.45  21           3    501   184  1.03  3.80                                      0  0  3  CAR SENT
0.52  27     2     2    501   170  0.73  4.17  101  1.80           0      12        0  0  3  CALL ENDED
0.52  14                                            402       4.7                           CAR ON PATROL
0.52                    402        1.44  2.82  402 21.29           1      11        0  0  3  QUEUE SERVICED
0.52  24     2     3    201    85  2.72  4.72  402  7.15           0      12        0  0  2  CALL ENTERS QUEUE
0.57  28     2     3    401   117  0.92  2.26                                      0  0  3  CALL ENTERS QUEUE
0.57  29     2     3    202    91  3.04  6.31                                      0  0  4  CALL ENTERS QUEUE
0.58  30     2     3    202    93  3.68  7.64                                      0  0  5  OUTSIDE CARS AREA
                                  199               301
```

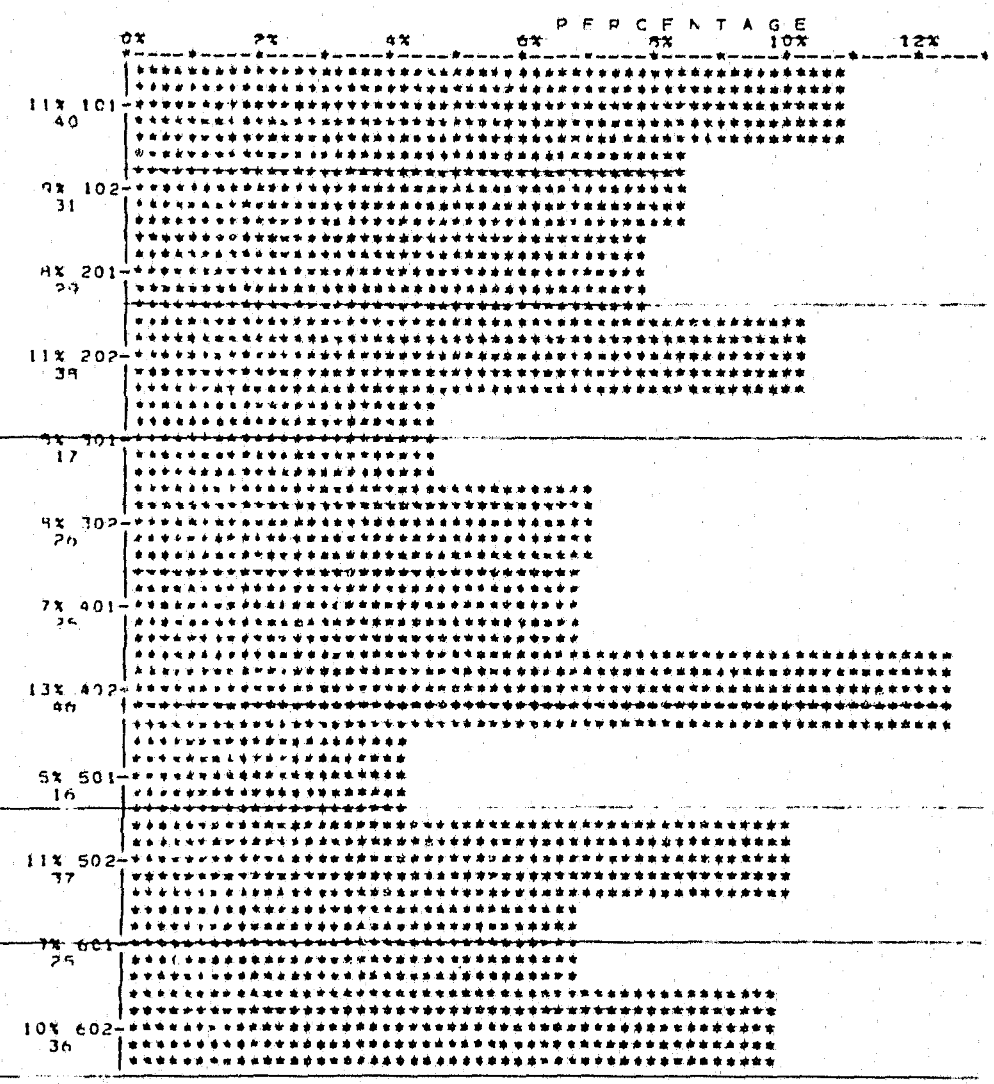
Fig. 22. Portion of a computer printout giving initial positions of patrol cars and call by call details of patrol operations. This simulation was with AD6Z1.12 zones, 60 calls per hour and DFCFS strategy.

ALL PRIORITIES

* DISTRIBUTION OF CALLS / ZONE *

ZONE NO.	NO. OF CALLS	PERCENT
101	40	10.93
102	31	8.47
201	29	7.92
202	38	10.38
301	17	4.64
302	26	7.10
401	25	6.83
402	46	12.57
501	16	4.37
502	37	10.11
601	25	6.83
602	36	9.84
TOTAL	366	100.00 %

1



TOTAL = 366

Fig. 23. Portion of a computer printout giving a table and histogram of calls per zone for the same simulation as Fig. 22.

IV. RESULTS OF SIMULATIONS

Main Results

Response Time

One of the criteria for evaluating patrol operations is the response time, which is defined as the elapsed time from receipt of a call for service (normally a telephone call) to the time a patrol car arrives on the scene. Response time includes dispatch delay (the time from initial police contact until an available unit is dispatched), queuing time (if there are no available cars), and travel time (the time taken to travel from the unit's initial position to the scene of the call for service). The response times deduced for Burnaby are shown in Figs. 24 and 25. In both diagrams the dispatch delay has been fixed at 3/4 minute, a time which might be changed as a result of more accurate measurements or an improved communications system. The response time is to a large extent dependent on the average number of calls received per hour and on the number of cars on duty.

If very few calls are being received (0–3 per hour), the response time depends mainly on travel time. With four cars on duty the response time would average about 5.5 minutes, while with 16–24 cars it would average about 3 minutes. As N (the average number of calls per hour) increases, the response time increases. If only four cars are available it soon becomes necessary to place calls in queue and the response time rapidly becomes unacceptably long. If 24 cars are on duty the response time increases only from 3 minutes to 5 minutes as N goes from 0 to 30 calls per hour. The practical application of these results is to help decide how many cars to place on duty. This is discussed in section V.

In Fig. 25 the response time is shown plotted against the average time between calls, ΔT. This method shows clearly the onset of saturation for different numbers of cars, that is, the onset of long queuing times leading to unacceptably long response times. For 4 cars, ΔT for the onset of saturation is about 10 minutes, or $N = 60/\Delta T = 6$ per hour, while for 24 cars, the onset is at about $\Delta T = 2.5$ minutes or $N = 24$ per hour.

It should be noted that the district dispatch and CWC reassignment invariably give the shortest response times. Figs. 24 and 25 and subsequent figures have therefore been plotted only for the DCWC strategy.

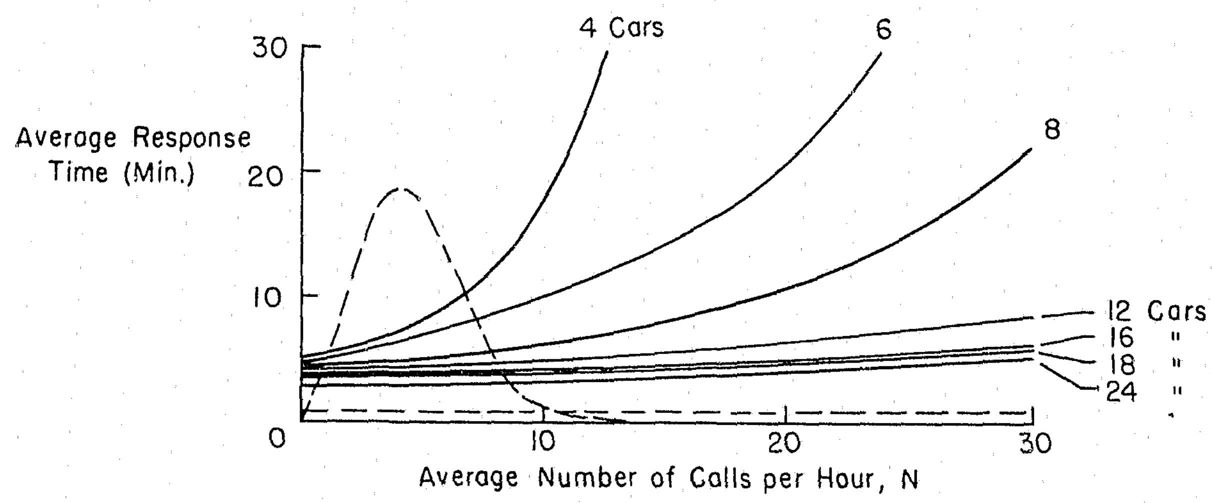


Fig. 24. Response times deduced from simulations. The distribution of calls per hour from Fig. 10 has been added as a dashed curve. The dispatch delay has been set at 3/4 minute, shown by a dashed straight line.

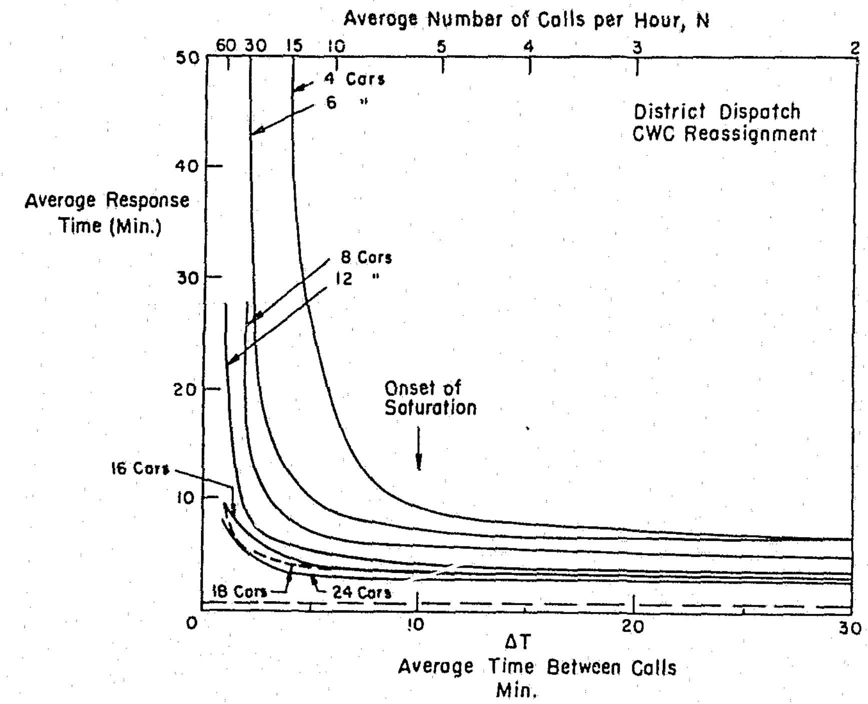


Fig. 25. Average response time as a function of average time between calls. The same data were used as for Fig. 24. The onset of saturation for 4 cars is shown.

Travel Time

The average travel time taken from the simulation is shown in Fig. 26, fitted with a negative exponential curve. It varies from a little over 2 minutes with 24 cars to over 4 minutes with 4 cars. These times are lower than would be expected from the times taken from log sheets shown in Fig. 13. Probably the average speed of 22 mph (taken from data for the Ottawa Police Force) used in the simulations should have been lower. An important point is that increasing the number of cars from 4 to 16 only reduces the average travel time by about 1 1/2 minutes. This indicates that when forecasting the number of cars to be put into operation the possibility of waiting in a queue is more important for response times than travel time.

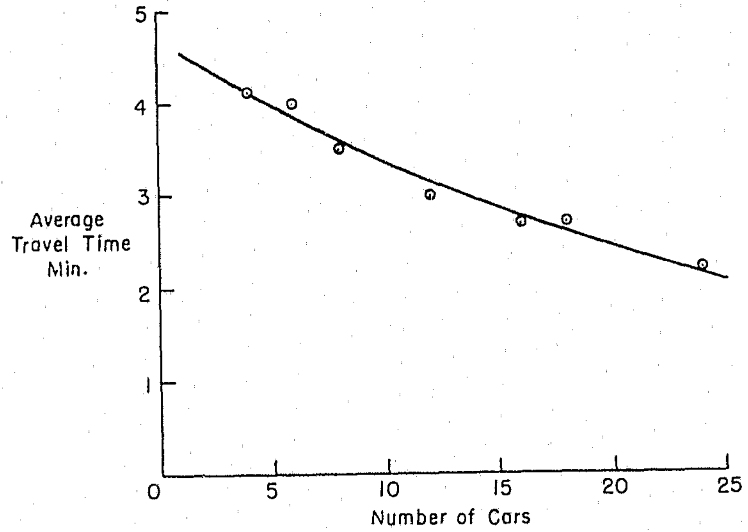


Fig. 26. Average travel time, T, taken from simulations. The times shown are short in comparison with times found during the data-taking session, shown in Fig. 13. See text for discussion. A negative exponential has been fitted to the circled points, with the equation $T = 4.666 \exp(-.03255)$ *where C = the number of cars.*

Workload (calls per 8 hour shift)

The workloads taken from the simulations are shown plotted on a graph in Fig. 27. The use of this graph is less straightforward than for Fig. 24, but may be illustrated by an example. The average workload for 13–28 March 1974, calculated from the data shown in Fig. 5, was 4.25 calls per 8 hours. A horizontal dashed line representing this workload has been drawn on Fig. 27, and from it we see that in a 4-car force each car would have a workload of 4.25 calls per shift with an average of 2.2 calls per hour; an 8-car force would have this workload with 4.25 calls per hour; a 16-car force with 8.4 calls per hour; and a 24-car force with 12.6 calls per hour.

It should be recalled that these workloads are deduced from simulations in which the average service time ranged from 5 to 15 minutes (Table VII). In very busy times (large N) there might be a tendency to reduce service times so that larger workloads could more readily be dealt with. The workloads deduced from Fig. 27 should therefore be regarded as applying best to quiet times.

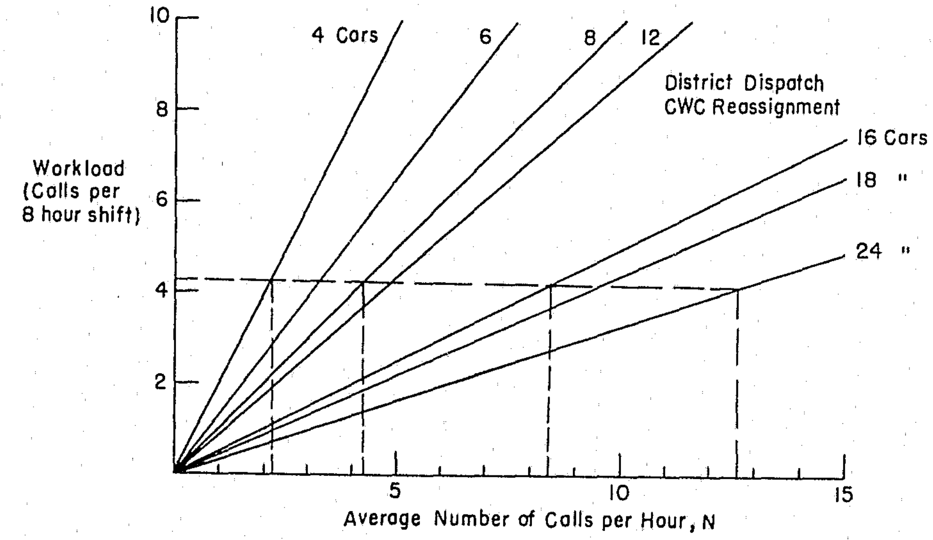


Fig. 27. Workloads as a function of average number of calls per hour and number of cars. The dashed lines are for an example discussed in the text.

Preventive Patrol Time

Preventive patrol time is defined here as time not occupied in traveling to a call or servicing it. This time is therefore available for preventive activities such as examining closed stores for signs of break-ins, zone familiarization, community interaction, administrative calls and so on. Clearly some balance between time spent on calls and on preventive patrol time must be found. The percentage of patrol time available during a shift is shown in Fig. 28. If no calls are received all time is available for preventive patrol, so all curves join at 100% and zero calls. As the number of calls per hour increases, a 4-car force rapidly becomes fully occupied so that at about 15 calls per hour it has no time available for patrol. At this rate of calls a 16-car force, on the other hand, has about 75% of its time available for preventive patrol. The number of hours available for preventive patrol during an 8-hour shift is shown in Fig. 29. Using the same example of about 15 calls per hour, we see that while a 4-car force would have no preventive patrol time available during an 8-hour shift, a 16-car force would have 98 hours. Selecting the optimum time required, and thus the optimum number of cars, is therefore a management decision.

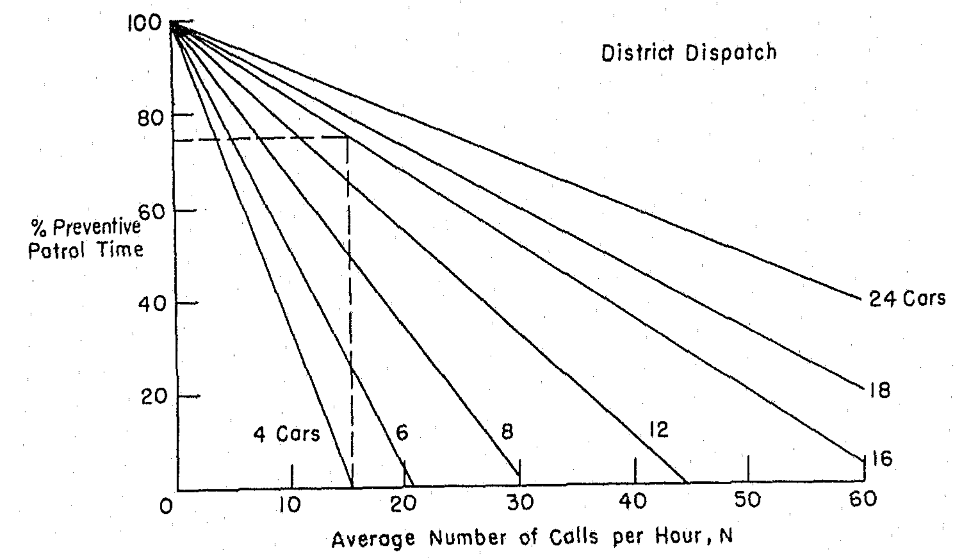


Fig. 28. Percentage of time available for preventive patrol. The dashed lines are for an example discussed in the text. Formulae for the curves are given in Section V.

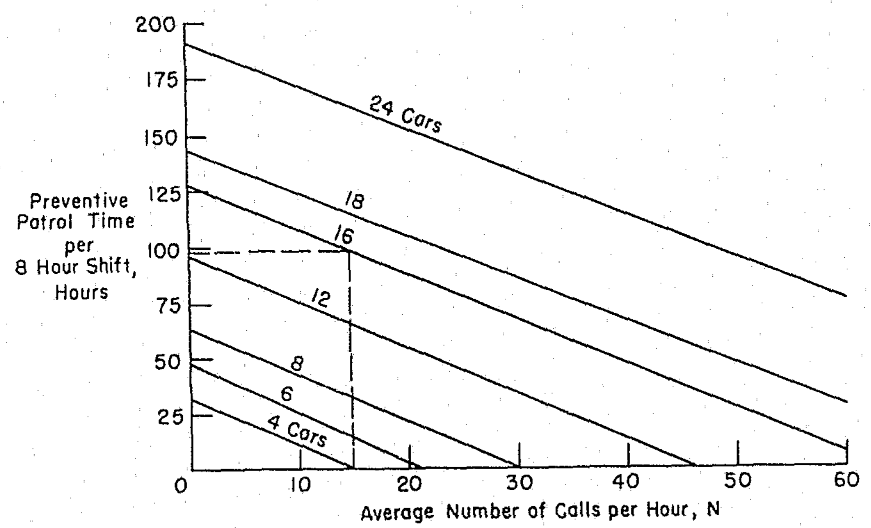


Fig. 29. Preventive patrol time per 8 hour shift. The dashed lines are for an example discussed in the text. Formulae for the curves are given in Section V.

Related Results

Queues

When the number of calls per hour is high there may not be enough cars on patrol to answer each call as it is received. It is therefore necessary to form a queue of calls waiting for service. The number of calls placed in queue directly affects the period of time before the arrival of police service, a delay to which the caller is sensitive and of which the force must be aware. The situation for Burnaby deduced from the simulations is shown in Figs. 30 and 31 and Table VIII and IX. In Fig. 30 the percentage of calls placed in queue is shown. With 4–8 cars on patrol the percentage of calls placed in queue rises rapidly, while with 12–24 cars on patrol the percentage in queue is reasonable for the highest numbers of calls likely to be received. The average wait in queue before dispatch of a car is shown in Fig. 31. Some examples will show the effect of wait in queue as a criterion for choosing the number of cars. Suppose a 10-minute wait is chosen for low-priority calls. Then if 10 calls per hour are expected a 4-car force would be satisfactory; 20 calls per hour would require an 8-car force; and 30 calls per hour about an 11-car force. However if a 3-minute wait was considered the maximum then at 10 calls per hour a 7-car force would be required; at 20 calls per hour, 12 cars; and at 30 calls per hour 17 cars.

The average number of calls in queue is shown in Table VIII and the maximum number of calls in queue in Table X. These results were taken directly from the simulations. As would be expected the number of calls in queue is zero or small for low average calls per hour but increases rapidly for up to 8 cars when the number of calls becomes high.

Saturation

If a certain number of cars are on patrol and the number of calls per hour becomes unexpectedly large the officers would be unable to handle the calls promptly, with long waiting times resulting. As an extreme example of this, suppose that 4 cars are on patrol and that 20 calls per hour start to arrive. Many of the calls could not be handled and would enter a queue to wait for service. (The most serious calls would be serviced first). Response times would become increasingly long and the force could be said to be in "saturation", or no longer able to handle incoming calls. From the simulations it was possible to predict the time at which Burnaby operations would become saturated. This was done by inspection of Fig. 25. The "onset of saturation" was estimated for each curve, and the results were plotted in a graph shown in Fig. 32. From the graph Table XI was prepared, showing the onset of saturation for various numbers of cars. Table XI may be used in planning patrol operations.

Another interpretation of saturation may be made from the simulations, which allow "operation" of the force under conditions which would or should never be encountered in reality. One such condition is to "operate" with so few cars and so many calls that it would be impossible to answer the calls in a reasonable time. In the simulations this was defined as having 100 calls in queue. The computer was programmed to stop the simulation if this

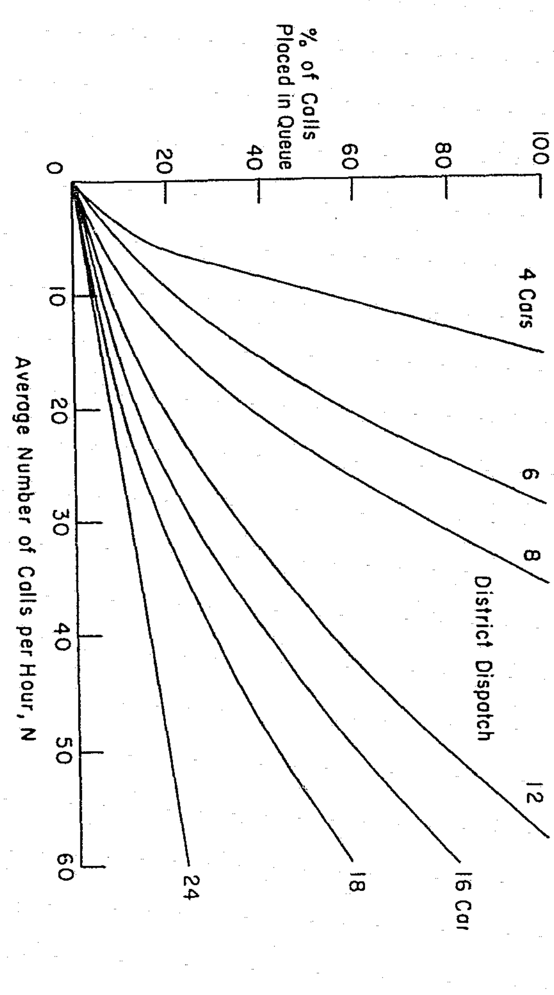


Fig. 30. Percentage of calls for service placed in a queue before dispatch of a car

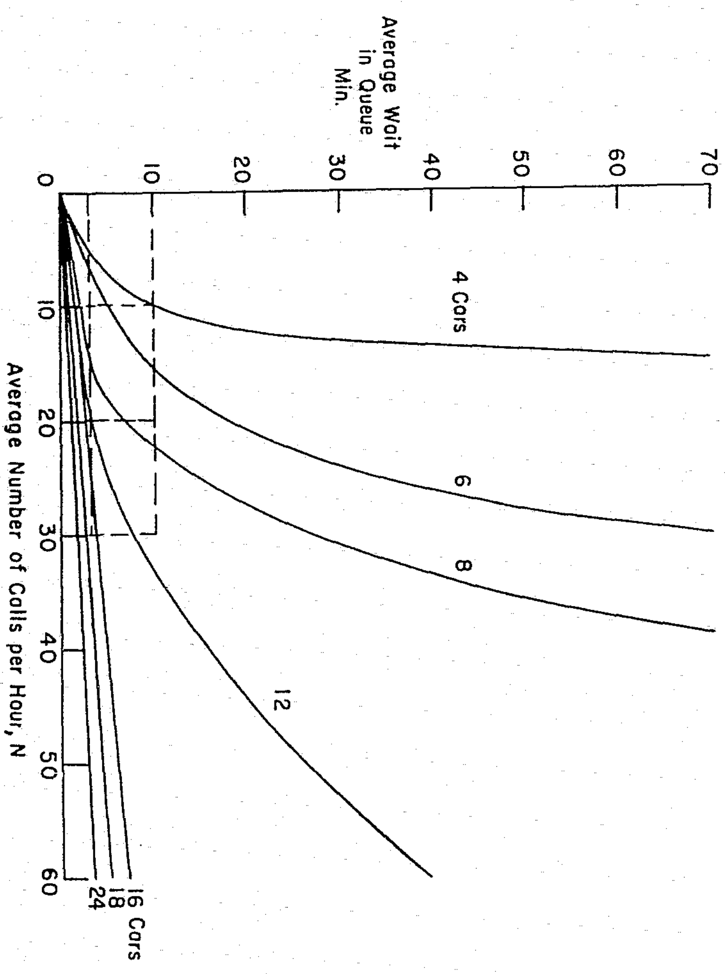


Fig. 31. Average wait in queue before dispatch of a car. The dashed lines refer to an example discussed in the text.

TABLE X. Maximum number of calls in a queue for service during simulation. Spaces showing 100 calls for simulations in saturation.

Zones and Number of Cars	Average Number of Calls per Hour, N and Strategy																	
	1.875		3.75				7.5		15				30		60			
	DCWC	ZCWC	DCWC	DFCFS	ZCWC	ZFCFS	DCWC	ZCWC	DCWC	DFCFS	ZCWC	ZFCFS	DCWC	ZCWC	DCWC	DFCFS	ZCWC	ZFCFS
JNO.4Z1.4	2	2	2	2	3	3	4	5	35	44	32	23	100	100	100	100	100	100
AD.6Z1.6	2	5	2	2	11	11	4	7	6	8	14	15	89	86	100	100	100	100
AD.6Z2A.6	2	5	1	1	11	11	3	7	10	12	14	15	84	86	100	100	100	100
AD.6Z2B.6	1	5	1	1	11	11	5	7	8	10	14	15	77	86	100	100	100	100
D1974.8	1	2	1	1	2	2	2	4	5	5	7	8	28	32	100	100	100	100
FL8Z1.8	2	2	2	2	2	2	2	4	3	3	8	9	32	46	100	100	100	100
JNO.4Z1.8	1	1	1	1	1	1	2	3	3	3	5	5	22	26	100	100	100	100
AD.6Z1.12	1	1	1	1	2	2	2	2	2	2	4	4	6	9	61	60	73	87
AD.6Z2A.12	1	1	1	1	2	2	1	2	3	3	4	4	8	9	55	66	73	87
AD.6Z2B.12	1	1	1	1	2	2	2	2	3	3	4	4	7	9	49	53	73	87
D1974.16	1	1	1	1	1	1	2	2	2	2	6	6	3	8	19	28	50	62
FL8Z1.16	1	1	1	1	1	1	1	1	2	2	5	5	3	7	17	20	40	27
JNO.4Z1.16	1	1	2	2	1	1	1	1	3	3	4	4	5	5	24	20	25	27
AD.6Z1.18	1	1	1	1	1	1	2	2	2	2	2	2	2	5	18	11	23	27
AD.6Z2A.18	1	1	1	1	1	1	1	2	2	2	2	2	3	5	15	14	23	27
AD.6Z2B.18	1	1	1	1	1	1	1	2	2	2	2	2	4	5	22	15	23	27
D1974.24	1	1	1	1	1	1	1	2	2	2	1	1	4	4	5	5	17	14
FL8Z1.24	1	1	1	1	1	1	1	1	2	2	2	2	2	3	4	4	9	13

TABLE XI. Onset of Saturation: the average number of calls per hour at the "onset of saturation", or number above which response times will become unacceptably long.

Cars on duty	Calls per hour at onset	Cars on duty	Calls per hour at onset
4	6	9	13
5	7.5	10	14
6	9	11	15
7	10.5	12	16
8	12	14	17.5

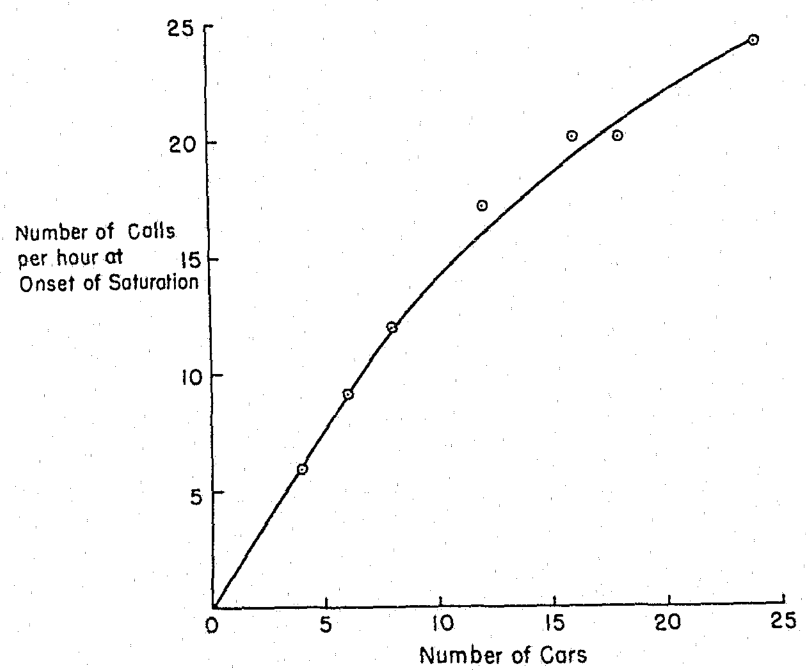


Fig. 32. Number of calls per hour at "onset of saturation", taken from curves derived from the simulation shown in Fig. 25.

occurred. Saturation occurred for 4, 6 or 8 car strategies with 30–60 calls per hour. The number of hours until this happened is shown in Table XII. Clearly it would be foolish to deploy only 4–8 cars when 30–60 calls per hour were expected.

A related parameter is the maximum number of cars simultaneously on call, shown in Table XIII. This table may be used to choose the minimum number of cars required for various average numbers of calls per hour. Thus if 1.865 calls per hour are expected 4 cars should be on patrol; for 3.75 - 7.5 calls, 6 cars; for 15 calls, 12 cars; for 30 calls, 16 cars and for 60 calls per hour, 24 cars.

Percentage of Calls in Car's Own Zone

In the simulations the percentage of calls which each car answers originating in the car's own zone is calculated for each priority. The remaining calls are interzone dispatches. The results, combined for all cars and all priorities, are given in Table XIV. In principle if one set of zones is better than another, the first set should have fewer interzone dispatches than the second. Thus the zones with the highest percentage of calls in home zone should be the "best". Inspection of Table XIV shows that choosing the "best" zones for one average number of calls per hour is seldom the "best" for another number.

Additional Details

The foregoing results were taken from the printouts of 324 computer simulations. Many steps were necessary before the mass of data contained in the printouts could be reduced to a comprehensible form. It therefore seemed pointless to include more details, but additional information may be obtained from the authors.

V. FORECASTING TABLES

Preparation

The patrol car and response time forecasting tables were prepared by combining several results. First the number of calls per hour was chosen from Fig. 10 to range from 2 to 16. From Fig. 24 it was decided that response times ranging from 3 to 20 minutes would be realistic. The number of cars required to achieve a particular average response time was then read from Fig. 24. Thus the first three columns (labeled N, Av. RT and No. C) were obtained in Table XIV.

When a certain number of patrol cars are on duty it is also important to know what proportion of their time will be available for preventive patrol. This was done with formulae using the results for preventive patrol shown in Fig. 28. The percentage of patrol time may be expressed (1) as

$$\%PT = 100 - KN \qquad (1)$$

where $\%PT$ = percentage of time each car has for preventive patrol,
K = a constant, and
N = number of calls per hour.

TABLE XII. Time to onset of saturation, defined as the number of hours from the beginning of the simulation until 100 calls (of all priorities) are in queue.

Zones and Numbers of Cars	Average Number of Calls per Hour, N, and Strategy					
	30		60			
	D C W C	Z C W C	D C W C	D F C F S	Z C W C	Z F C F S
JNO.4Z1.4	7.6	7.9	2.5	2.5	2.5	2.5
AD.6Z1.6			3.3	3.3	3.4	3.3
AD.6Z2A.6			3.2	3.2	3.4	3.3
AD.6Z2B.6			3.4	3.1	3.4	3.3
D1974.8			3.9	3.9	3.7	3.6
FL8Z1.8			3.7	4.2	3.4	3.2
JNO.4Z1.8			3.8	3.6	3.6	3.7

TABLE XIII. Maximum number of cars simultaneously on call during a simulation. The dashed lines may be used to choose the minimum number of cars required to deal with a certain N.

Zones and Number of Cars	Average Number of Calls per Hour, N, and Strategy																	
	1.875		3.75				7.5		15				30		60			
	D C W C	Z C W C	D C W C	D F C F S	Z C W C	Z F C F S	D C W C	Z C W C	D C W C	D F C F S	Z C W C	Z F C F S	D C W C	Z C W C	D C W C	D F C F S	Z C W C	Z F C F S
JNO.4Z1.4	3	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
AD.6Z1.6	4	3	4	4	5	5	6	5	6	6	6	6	6	6	6	6	6	6
AD.6Z2A.6	3	3	5	5	5	5	6	5	6	6	6	6	6	6	6	6	6	6
AD.6Z2B.6	4	3	5	5	5	5	5	5	6	6	6	6	6	6	6	6	6	6
D1974.8	4	3	4	4	4	4	7	5	8	8	7	7	8	8	8	8	8	8
FL8Z1.8	4	4	4	4	3	3	7	6	8	8	7	7	8	8	8	8	8	8
JNO.4Z1.8	4	4	4	4	4	4	6	6	8	8	8	8	8	8	8	8	8	8
AD.6Z1.12	3	3	5	5	4	4	6	7	9	9	8	8	12	11	12	12	12	12
AD.6Z2A.12	3	3	4	4	4	4	7	7	8	9	8	8	12	11	12	12	12	12
AD.6Z2B.12	3	3	4	4	4	4	7	7	11	11	8	8	12	11	12	12	12	12
D1974.16	3	3	5	5	4	4	7	6	11	11	9	9	14	13	16	16	16	15
FL8Z1.16	4	4	5	5	5	5	7	7	10	10	9	9	14	12	16	16	16	16
JNO.4Z1.16	4	4	5	5	5	5	6	6	11	11	8	8	14	14	16	16	16	16
AD.6Z1.18	4	3	4	4	4	4	8	7	9	9	9	9	13	14	18	18	18	18
AD.6Z2A.18	4	3	4	4	4	4	5	7	11	11	9	9	14	14	18	18	18	18
AD.6Z2B.18	3	3	4	4	4	4	7	7	9	9	9	9	14	14	18	18	18	18
D1974.24	3	3	4	4	5	5	7	8	9	9	9	9	15	12	24	24	23	21
FL8Z1.24	3	3	5	5	6	4	10	10	10	10	15	14	15	14	21	21	20	23

TABLE XIV. Percentage of calls in car's own zone. (District dispatch)

Zones and Number of Cars	Average Number of Calls per Hour								
	1.875	3.75		7.5	15		30	60	
	DCWC	DCWC	DFCFS	DCWC	DCWC	DFCFS	DCWC	DCWC	DFCFS
JNO.4Z1.4	83	81	78	63	38	35	-	-	-
AD.6Z1.6	73	64	64	64	45	41	30	-	-
AD.6Z2A.6	78	88	78	64	57	55	46	-	-
AD.6Z2B.6	89	85	85	80	59	62	50	-	-
D1974.8	47	44	44	38	32	37	29	-	-
FL8Z1.8	78	74	74	68	53	53	27	-	-
JNO.4Z1.8	93	89	89	89	72	72	47	-	-
AD.6Z1.12	86	82	82	90	78	78	52	23	32
AD.6Z2A.12	89	88	88	88	77	79	63	52	48
AD.6Z2B.12	91	90	90	90	86	86	68	51	43
D1974.16	88	90	91	85	73	74	63	34	33
FL8Z1.16	85	87	87	87	81	81	74	36	33
JNO.4Z1.16	92	95	95	93	90	89	75	40	56
AD.6Z1.18	86	89	89	89	87	87	75	36	42
AD.6Z2A.18	89	93	93	94	85	85	81	54	40
AD.6Z2B.18	95	96	96	94	91	91	83	66	62
D1974.24	92	91	91	88	87	86	73	56	56
FL8Z1.24	96	89	89	88	82	80	81	62	61

A value of K must be calculated for each number of patrol cars selected, by reading the intercept with the x-axis of the curve in Fig. 28 and solving K = 100/(Intercept.). For example, for 6 cars the intercept is 20.8 calls per hour and K = 100/20.8 = 4.81. Values of K for numbers of cars not shown in Fig. 28 were found by interpolation.

Similarly the number of hours of preventive patrol time the cars will have during an 8 hour shift, HrPT, was calculated using the formula

$$HrPT = 8(No.C) - BN \qquad (2)$$

where No. C = number of cars on patrol, and

B = a constant

The constant B is the slope of the lines shown in Fig. 29 and was calculated as 2.02. Thus, for example, if 6 cars were on duty and 8 calls per hour were being dispatched we would have HrPT = 8(6) - 2.02(8) = 32 hours. Columns 4 and 5 of Table XIV were calculated using these procedures. Table XVI was prepared using the same procedures and formulae in a different order.

Use

The forecasting tables may be used to plan the number of cars for a particular period when a certain number of calls per hour are expected, including the likely effect should the number of calls change during this period. Table XV shows the number of patrol cars needed to maintain a certain average response time when a certain average number of calls per hour are being received. Table XV may be used as follows. Suppose that during a certain shift (whose calls could be depicted by Fig. 9) 5 calls per hour were expected and a 5 minute response time was desired. From Table XV we see that 8 cars would be required to maintain this level of response. Also we see that with 8 cars on duty 84% of the time would be available for preventive patrol or duties other than answering calls. During an 8 hour shift there would be 54 man-hours available for these duties.

Table XVI gives the same data arranged in a different way. If 8 cars are on duty and 5 calls per hour are arriving we again have a 5 minute response time, 84% preventive patrol time and 54 hours of preventive patrol time. Suppose now that the number of calls suddenly increases to 10 per hour. The average response time would increase to 6 minutes, preventive patrol time to 67% and hours of preventive patrol to 44. This level of calls would still be below the onset of saturation (12 calls per hour from Table X) so this increase in calls per hour could adequately be handled by 8 cars.

Tables XI, XV and XVI may be used for planning patrol car deployment. Since they are based on the limited amount of data taken 13–26 March 1974, however, they should be used with caution until their predictions are verified.

TABLE XV

Patrol Car Forecasting Table

R.C.M.P. Burnaby Detachment
Based on data obtained 13 – 26 March 1974

N = number of calls per hour expected to which a radio car will be dispatched.
Av RT = average response time desired, in minutes.
No. C = number of cars required to achieve this Av RT.
% PT = percentage of time each car has for preventive patrol.
Hr PT = number of hours of preventive patrol time the cars will have during an 8 hour shift.

N	Av RT	No. C	% PT	Hr PT	N	Av RT	No. C	% PT	Hr PT
	3	24	98	188		3	24	97	186
	4	13	96	100		4	15	95	114
	5	7	92	52		5	7	88	50
2	6	4	87	28	3	6	6	86	42
	7	4	87	28		7	4	82	26
	8	4	87	28		8	4	82	26
	9	4	87	28		9	4	82	26
	10	4	87	28		10	4	82	26
	3	24	96	184		3	24	95	182
	4	15	93	112		4	16	92	118
	5	7	84	48		5	8	84	54
4	6	6	81	40	5	6	7	84	46
	7	5	78	32		7	6	76	38
	8	4	74	24		8	4	67	22
	9	4	74	24		9	4	67	22
	10	4	74	24		10	4	67	22
	3	24	94	180		3	24	93	178
	4	16	90	116		4	16	89	114
	5	9	82	60		5	11	83	74
6	6	7	77	44	7	6	8	77	50
	7	7	77	44		7	7	73	42
	8	5	67	28		8	6	66	34
	9	4	61	20		9	5	61	26
	10	4	61	20		10	4	54	18
	3	>24				3	>24		
	4	17	88			4	18	88	126
	5	12	82	80		5	12	80	78
8	6	8	74	48	9	6	8	71	46
	7	7	69	28		7	7	65	38
	8	6	61	32		8	7	65	38
	9	6	61	32		9	6	57	30
	10	5	56	24		10	6	57	30
	4	18	87	124		4	18	84	120
	6	9	67	52		6	10	68	56
	8	7	61	36		8	8	61	40
	10	6	52	28		10	7	53	32
10	12	5	45	20	12	12	6	42	24
	14	5	45	20		14	5	34	16
	16	5	45	20		16	5	34	16
	18	4	35	12		18	5	34	16
	20	4	35	12		20	5	34	16
	4	19	82	124		4	20	81	128
	6	11	66	60		6	12	64	64
	8	8	54	36		8	9	53	40
	10	7	46	28		10	8	48	32
14	12	6	33	20	16	12	7	38	24
	14	6	33	20		14	6	23	16
	16	6	33	20		16	6	23	16
	18	5	23	12		18	6	23	16
	20	5	23	12		20	5	12	8

TABLE XVI

Response Time Forecasting Table

R.C.M.P. Burnaby Detachment
Based on data obtained 13 – 26 March 1974

No. C = number of radio patrol cars on duty
N = number of dispatched calls per hour
Av RT = average response time to be expected with this No. C and N
% PT = percentage of time each car has for preventive patrol
Hr PT = number of hours of preventive patrol time the cars will have during an 8 hour shift.

No. C	N	Av RT	% PT	Hr PT	No. C	N	Av RT	% PT	Hr PT	No. C	N	Av RT	% PT	Hr PT
	2	7	87	28		2	6	89	36		2	5	90	44
	3	7	82	26		3	6	83	34		3	6	86	42
	4	8	74	24		4	7	78	32		4	6	81	40
	5	8	67	22		5	7	72	30		5	7	76	38
	6	9	61	20		6	8	67	28		6	7	71	36
4	7	10	54	18		7	9	61	26		7	8	66	34
	8	12	48	16	5	8	10	56	24	6	8	8	61	32
	9	15	41	14		9	12	50	22		9	9	57	30
	10	18	35	12		10	12	45	20		10	10	52	28
	12	27	22	8		12	14	34	16		12	12	42	14
	14	>30				14	18	23	12		14	12	33	20
	16	>30				16	20	12	8		16	14	23	16
	2	5	92	52		2	4	93	60		2	4	94	68
	3	5	88	50		3	4	90	58		3	4	91	66
	4	5	84	48		4	5	87	56		4	5	88	64
	5	6	84	46		5	5	84	54		5	5	85	62
	6	6	77	44		6	5	80	52		6	5	82	60
	7	7	73	42	8	7	6	77	50	9	7	5	79	58
7	8	7	69	40		8	6	74	48		8	6	77	56
	9	7	65	38		9	6	71	46		9	6	74	54
	10	8	61	36		10	6	67	44		10	6	67	52
	12	10	53	32		12	8	61	40		12	7	65	48
	14	10	46	28		14	8	54	36		14	8	59	44
	16	12	38	24		16	10	48	32		16	8	53	40
	2	4	95	76		2	4	95	84		2	4	95	92
	3	4	92	74		3	4	93	82		3	4	93	90
	4	5	89	72		4	4	90	80		4	4	91	88
	5	5	87	70		5	5	88	78		5	5	89	86
	6	5	84	68		6	5	85	76		6	5	87	84
10	7	5	81	66	11	7	5	83	74	12	7	5	84	82
	8	5	79	64		8	5	81	72		8	5	82	80
	9	5	76	62		9	5	78	70		9	5	80	78
	10	6	73	60		10	5	76	68		10	5	78	76
	12	6	68	56		12	6	71	64		12	5	73	72
	14	7	63	52		14	6	66	60		14	6	69	68
	16	7	57	48		16	7	61	56		16	6	64	64
	2	4	96	108		2	4	97	124		2	4	97	140
	3	4	94	106		3	4	95	122		3	4	96	138
	4	4	92	104		4	4	94	120		4	4	95	136
	5	4	91	102		5	4	92	118		5	4	93	134
	6	4	89	100		6	4	90	116		6	4	92	132
14	7	4	87	98	16	7	4	89	114	18	7	4	91	130
	8	5	85	96		8	4	87	112		8	4	89	128
	9	5	83	94		9	4	86	110		9	4	88	126
	10	5	81	92		10	4	84	108		10	4	87	124
	12	5	78	88		12	4	81	104		12	4	84	120
	14	5	74	84		14	5	78	100		14	4	81	116
	16	6	70	80		16	5	74	96		16	4	79	112
	2	3	98	156		2	3	98	172		2	3	98	188
	3	3	96	154		3	3	97	170		3	3	97	186
	4	3	95	152		4	3	96	168		4	3	96	184
	5	3	94	150		5	3	95	166		5	3	95	182
	6	3	93	148		6	3	93	164		6	3	94	180
20	7	4	91	146	22	7	3	92	162	24	7	3	93	178
	8	4	90	144		8	3	91	160		8	3	92	176
	9	4	89	142		9	3	90	158		9	3	91	174
	10	4	88	140		10	4	89	156		10	3	90	172
	12	4	85	136		12	4	87	152		12	3	88	168
	14	4	83	132		14	4	85	148		14	3	86	164
	16	4	81	128		16	4	82	144		16	4	84	160

VI. SUGGESTIONS FOR OPERATION*

It is suggested that records of occurrences include the atom number, time and a number indicating the type of occurrence. If this is done a continuing record of occurrences – atom by atom and hour by hour – will be acquired which should be valuable both as record of past occurrences and as an aid in forecasting. Also the number of calls per hour during various times of the day, days of the week, and seasons of the year will become known and facilitate the use of Tables XV–XVI for forecasting patrol operations. The use of a computer as an aid in keeping track of these data should be considered

It is suggested that one of the arrangements of zones worked out by the authors on the basis of equal workloads be adopted. The division into zones should be reviewed from time to time, say every 1–2 years, so that changes in the pattern of occurrences can be dealt with.

Finally, it is suggested that Tables X, XV and XVI be used for determining manpower requirements for various shifts. A logical step after forecasting the number of calls per hour is to make appropriate shift schedules. Such schedules were beyond the scope of the work described here, but it is hoped that the results will be useful for this purpose.

* Some of the suggestions have already been adopted.

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