Microcomputer Allocation of Manpower to Illinois State Police Districts

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ABSTRACT

Mathematical models developed to allocate police officers have been oriented toward urban policing. As such, they depend on a backup police unit to service a call when the primary unit is not available. The number of units assigned minimizes response time while maximizing use of available manpower. Policing in a large geographic area such as a state has different constraints. Secondary responding units rarely are available immediately. Allocation of a scarce resource statewide must equitably satisfy both the high and low demand for services, and it must provide visible preventive patrol. The model developed for the Department of Law Enforcement of the state of Illinois attempts to provide adequate administrative assignment, satisfy demands for response, and equalize patrolling. Administrative support required to run the operation both centrally and on the district level is decided a priori. It is excluded from the mathematical allocations. Response to calls for service is handled by individual patrolling units with one or more officers. The number required depends on the expected number of calls and their duration. On the other hand, patrolling visibility is dependent on the size of the rural population and the length and volume of traffic on various types of rural highways. This model can be run on a microcomputer. Its current version allows allocations for up to 110 counties combined into 30 district commands. The processes are described briefly and the output generated is shown. It is also shown that the model is applicable to uses other than those of state police.

The Illinois Department of Law Enforcement (DLE) required a method for allocating officers throughout the state. Procedures originally used had been designed around obligated and unobligated time (1). These, however, gave too much weight to service in urban areas and tended to ignore rural areas. Existing mathematical models developed by Larson (2), Chaiken (3), and LeGrande (4) also apply to urban areas. They depend on availability of more than one unit to service a call and minimize response time. On a statewide basis, this condition does not exist. Response time is measured in the tens of minutes and is not as critically related to the police role as it is in an urban area. Finally, preventive patrol plays an important role.

In designing a model for the DLE state police, two factors were taken into account: balancing response to calls for service and providing a visible patrol throughout the state. Further, because the state police operate from more than two semiindependent substations, called districts, allocations had to account for administrative activity.

A model for the Division of State Police was developed in 1981. By 1982, the department was operating it on the main computer. State police executives were using it to help plan staffing for district operations, to assign newly graduated officers, and to support budget requirements. Several reports by Raub and Sweat have described this model in great detail (5,6). To make it more efficient, the methodology has been revised and programmed for a microcomputer (Apple II Plus in BASIC). This paper describes the model briefly and shows the type of output available.

METHODOLOGY

General Description

The model has three sections: administrative support, response to calls for service, and preventive patrol, which is titled Policing and Patrolling. Administrative support is fixed by the police executives for districts and the central office. Allocations for the other two sections are computed for each county for the three shifts and then aggregated to districts (Figure 1). There is flexibility in that either a fixed body of officers can be allocated or the total strength required can be computed from a given set of parameters.

Administrative Support

The number of officers needed to administer the state police are established externally to the model. Each district commander along with the superintendent and staff review their needs for command personnel and for officers assigned to specialized details such as public information. Officers in these categories are not expected to be available, generally, to respond to accidents or to patrol. This group constitutes the administrative support. It is subtracted from the number of officers to be assigned before operation of the model.

The administrative support is established for each district as well as for the central office. Its distribution is shown on the output summary sheet. That a given number of officers is assigned to administrative support in a district does not affect how the model assigns the remaining officers to that district. All districts receive allocations of remaining officers (after subtracting administrative support) based on the needs of those districts.

Calls for Service

Officers must be available to answer calls for service. These are classified as responses to events normally not seen on patrol. The two that account for most of the time are accidents and criminal com-

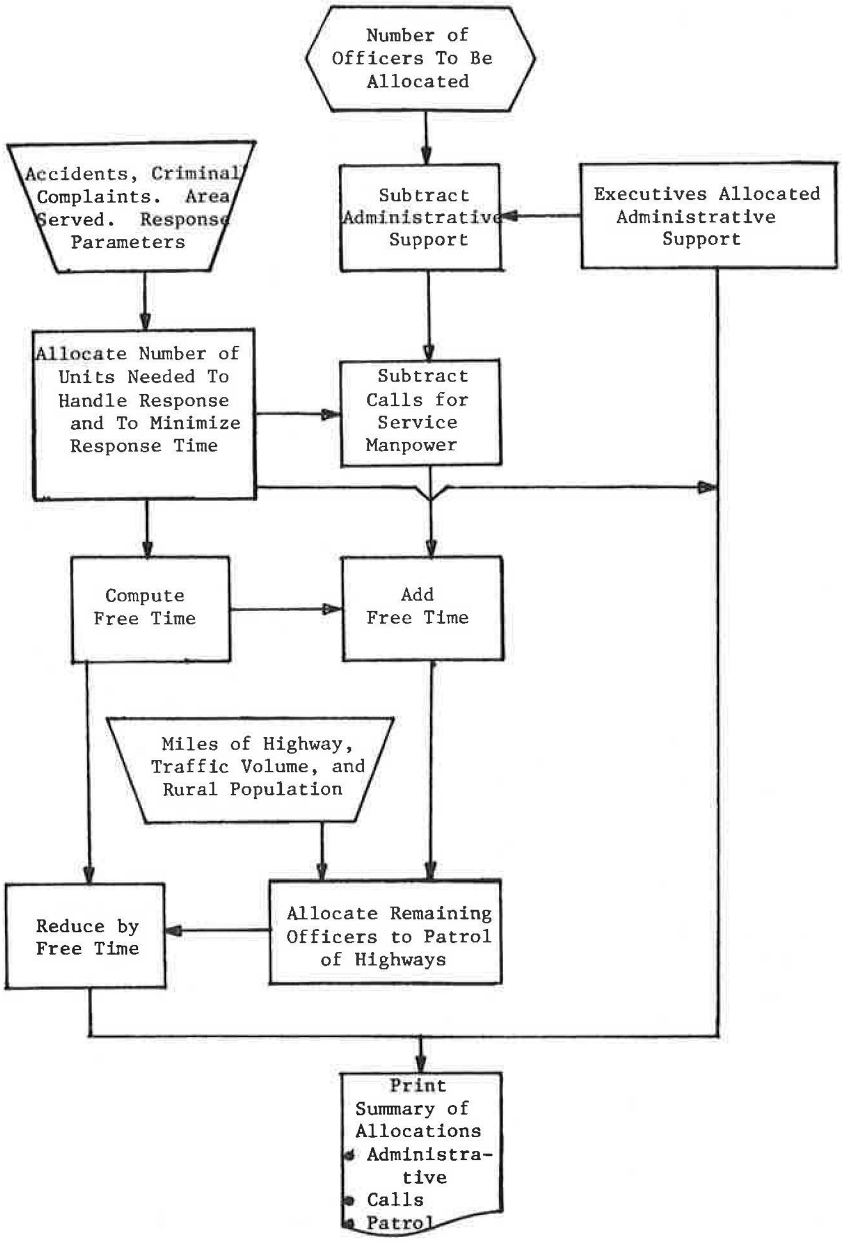

FIGURE 1 Allocation methodology.

plaints. In both cases, these responses are limited to events in rural areas, except for accidents occurring on all Interstate highways outside the city of Chicago.

The bases for assignment are accidents and criminal complaints handled in the previous year. There is potential for bias resulting from using self-reported statistics; however, the occurrence of both events is beyond the control of the police. Also known for each accident and criminal complaint is the average time taken to handle one event. Their occurrence, because it is random, is best predicted by a Poisson distribution using for lambda a uniform expected rate during the time required to handle one event.

The model assumes that one patrolling unit is assigned to one event. Therefore, by predicting the percentage of the time that zero, one, two, or more events will occur, it predicts the number of patrolling units required. At some point, the addition of patrolling units is not practical. If one unit will handle 95 percent of all occurrences, the second will handle less than 5 percent. Addition of a second unit may not be practical in terms of resources expended to serve a small fraction of activity. In reality, the police do not handle all events as they occur. The queue is served from other resources including other law enforcement agencies, delayed response, or reassignment of an active unit. Therefore, the limit to assignment of patrolling units is set at a service level expressed at some percentage less than 100.

Average rate of event occurrence per shift (lambda):

$$m_s = tpX'_s/(365h_s) \qquad (1)$$

where

m_s = lambda or average rate per period t;
t = time taken to handle one event, accident, or criminal complaint;
p = proportion handled (used to adjust arrival

rates when other conditions are being tested);

X_s' = number of accidents or criminal complaints during shift s; and

h_s = hours of work during shift s for each of 365 days.

Likelihood of event occurrence:

$$P(X)_s = \exp(-m_s) m_s^X / X! \quad (2)$$

$$\text{Repeat until } \sum_s P(X)_s \geq q_s \quad (2a)$$

where

$P(X)_s$ = probability of X events occurring during shift s,

exp = natural log,

X = any integer $\geq$ 0, and

q_s = proportion of calls (accidents or criminal complaints) to be served immediately during shift s.

Note: $P(X)_s$ is computed separately for accidents and for criminal complaints.

The model solves for the number of units needed for each shift within a county to respond to accidents and criminal complaints. These are combined to become number of units required for calls for service. Because of the relative infrequency of events in many locations, zero units will be required. Yet, because of the statewide function of the police, there must be a unit available, even if that patrol covers more than one county.

The number of patrols required if there are insufficient patrols to handle calls for service then is the number needed to meet a maximum response time for each shift. State police executives establish this maximum for each shift. The number of patrols needed to meet the maximum response time is the average travel time between any two points divided by the maximum response time. Congestion and the type of roads available are considered in the equation when the number of patrols required is computed. The average mileage that translates to travel time in two counties may be the same, but because congestion reduces the average response speed in one, the number of patrols required to meet the response time differs. For the model, congestion is a function of average daily traffic (ADT); its formulation is based on the AASHTO results (7,p.96). Although this is a simplistic approach, its purpose is to distinguish between rural and urban areas; it is not for precision.

Reduction in speed for congestion:

Interstate

$$f_j = [55 - 0.07(V_j w_s)^{1/2}]/55 \quad (3a)$$

Two-lane heavily traveled

$$f_k = [55 - 0.04(V_k w_s)^{1/2}]/55 \quad (3b)$$

where

f_j, f_k = reduction in speed resulting from congestion on Interstate (j) and heavily traveled two-lane roads (k),

55 = assumed maximum speed and basis from which congestion is computed,

w_s = proportion of ADT during shift s, and

V_j, V_k = ADT on Interstate (j) and heavily traveled two-lane roads (k).

Reduction in emergency response speed:

$$v' = (f_j M_j + f_k M_k)/(M_j + M_k) \quad (4)$$

where v' is the proportionate decrease in emergency driving speed and M_j, M_k is the miles of highway in any county, Interstate (j), and heavily traveled two-lane road (k).

Number of patrols required to serve maximum response:

$$X_d' = 2(Q)^{1/2}/3(d_s v') \quad (5)$$

where

X_d' = number of patrols required to minimize response time,

d_s = maximum response time during shift s, and

Q = area of a county in square miles.

The number of units assigned to calls for service or response time (Figure 2) depends on which need is greater. These then are aggregated by shift and then by county into districts. Patrolling positions are converted to officers. It takes between 1.5 and 2.0 officers to serve one patrolling position on a year-round basis. This value is derived from the number of annual hours in a shift divided by the number of manhours of work performed annually by one officer. For the model, the number of manhours worked per year is entered as a parameter.

Number of patrols to handle call:

$$X_c' = \max(X_a' + X_b', X_d') \quad (6)$$

where

X_c' = number of patrols needed to handle calls for service,

X_a' = number of patrols to handle accidents from the integer X in Equation 2 that satisfies expression 2a, and

X_b' = number of patrols to handle criminal complaints from expression 2a.

Number of officers:

$$X_c = X_c' c_s \quad (7)$$

where X_c is the number of officers assigned and c_s is the conversion factor for patrols to officers found from dividing annual manhours by manhours worked per officer.

When a fixed number of officers is allocated, the number required for calls could exceed the available amount. Decreases in allocation would arise from reducing the percentage of calls served immediately or increasing response time. A sample of the output received from a microcomputer for this section is shown as Figure 3.

Policing and Patrolling

After administrative support and calls for service are subtracted, some officers remain unallocated. In addition, some officers who have been allocated to calls for service may not be busy with a call. Only a small percentage of the manhours allocated to calls for service is required to handle those services. Much of the time is available for other work or is not obligated. This time is also available for preventive patrol. The total of officers not assigned and not obligated is allocated to patrolling highways and assisting local law enforcement officers as shown in Figure 4.

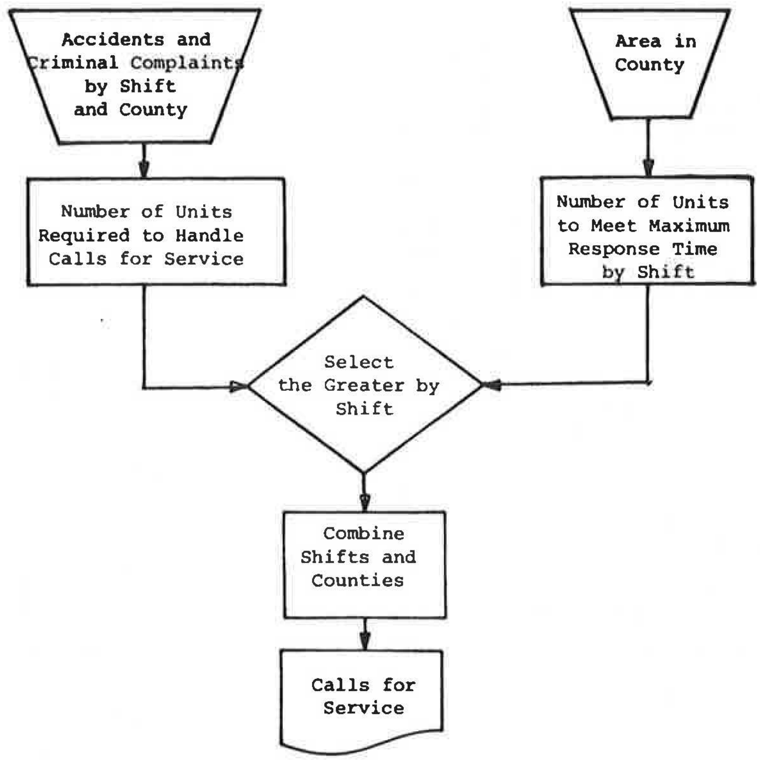

FIGURE 2 Allocating to calls for service.

Manpower to be allocated 380
Allocated to calls 113.2

ACCIDENTS

	Total	Shift 1st		2nd		3rd	
Dist.	NBR	NBR	POS	NBR	POS	NBR	POS
1	4154	671	2.0	1850	5.0	1633	5.0
2	7280	1020	2.0	2950	6.0	3310	7.0
3	1308	261	0.0	484	5.0	563	5.0
4	876	186	0.0	331	4.0	359	4.0
TOT	13618	2138	4.0	5615	20.0	5865	21.0

CRIMINAL COMPLAINTS

	Total	Shift 1st		2nd		3rd	
Dist.	NBR	NBR	POS	NBR	POS	NBR	POS
1	2142	530	2.0	966	3.0	646	3.0
2	3701	886	2.0	1730	4.0	1085	3.0
3	519	97	0.0	232	0.0	190	0.0
4	1237	247	1.0	474	1.0	516	2.0
TOT	599	1760	5.0	3402	8.0	2437	8.0

MINIMUM RESPONSE
Positions Per Shift

	Shift		
Dist.	1st	2nd	3rd
1	.4	1.6	1.6
2	.2	1.0	1.0
3	1.1	4.3	4.3
4	.8	3.1	3.1

TOTAL MANPOWER ALLOCATED
Positions Per Shift

	Shift				
Dist.	1st	2nd	3rd	Total Officers	Equiv. Patrols
1	4.0	8.0	8.0	33.2	22.3
2	4.0	10.0	10.0	39.8	20.7
3	1.1	5.3	5.2	19.2	16.1
4	1.6	5.0	6.0	20.9	17.0
TOT	10.7	28.3	29.2	113.2	76.1

Totals

Accidents	13618
Criminal Response	7599
Allocated to Calls	113.2

FIGURE 3 Microcomputer output: calls for service.

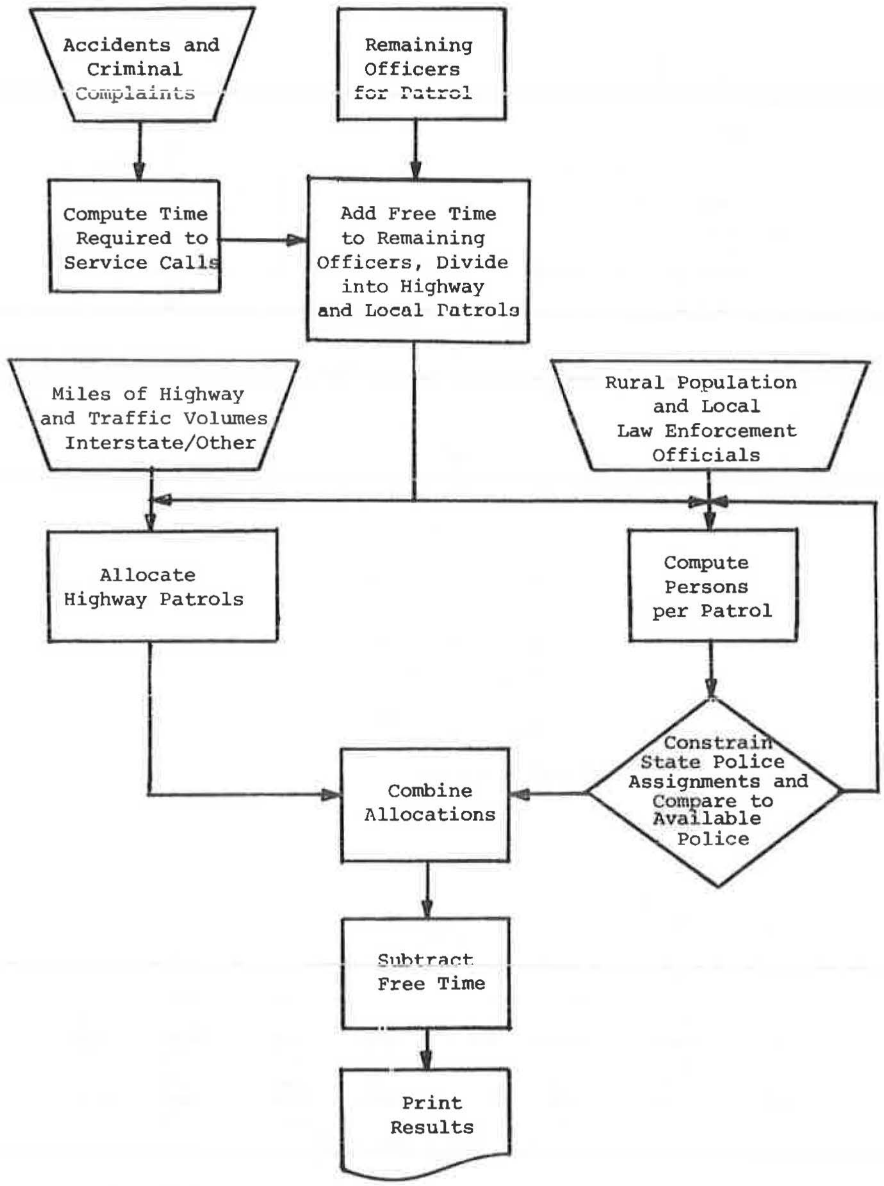

FIGURE 4 Policing and patrolling allocations.

Officers available:

$$X_p = T - O - X_c \quad (8)$$

where

X_p = officers not otherwise allocated,
T = total strength, and
O = administrative support.

Adjusted number including unobligated time:

$$X_p' = \{X_p + [(m - m')(X_c - \bar{t}C)]/m\}/c_s \quad (9)$$

where

X_p' = equivalent positions for patrol;
m = number of annual manhours worked per officer;
m' = number of nonproductive hours, generally represented by 2 hr for each working day ($m' = 2m/h_s$, where h_s is hours of work during shift s for each of 365 days);
$\bar{t}$ = average time to handle one call (accident or criminal complaint); and
C = number of calls (accidents and criminal complaints).

Available for patrol:
Interstate

$$X_f' = p_f X_p' \quad (10a)$$

All other highway

$$X_o' = p_o X_p' \quad (10b)$$

Rural law enforcement

$$X_r' = p_r X_p' \quad (10c)$$

where X_f', X_o', and X_r' are positions available for Interstate and two-lane patrol and for rural law enforcement and p_f, p_o, and p_r are proportion of positions to be assigned to Interstate patrol, other highway patrol, and as assistance to local law enforcement officers.

In allocating positions to patrolling, the user has the option of how much weight, in terms of percentage of available positions, is placed on each of the three categories of patrol: Interstate highway, other highway, and assistance to local law enforcement personnel. Distribution of positions by the model to counties is made according to the miles of highway based on the average speed of a patrolling vehicle, which is a function of congestion and stops to handle traffic incidents. Assistance to local law enforcement is dependent on the rural population.

Volume of traffic affects the number of miles to be patrolled. The annual time taken for traffic enforcement and assistance to motorists shows a strong linear relationship to daily vehicle miles. This time is subtracted from available time before patrolling mileage is computed. The amount of miles that can be patrolled depends on patrolling speed; this decreases because of congestion, which has earlier been shown as a function of ADT. Because a fixed number of officers is being allocated among all highway mileage, the average miles of patrol per unit is solved. The following equations show the solution for both Interstate and other highways.

Time required for traffic-related work:

$$t_j = 0.96 M_j V_j w_s \quad (11a)$$

$$t_k = 3.56 M_k V_k w_s \quad (11b)$$

$$t_l = 1.15 M_l V_l w_s \quad (11c)$$

where

t_j, t_k, t_l = time in hours required to enforce traffic laws,
M_j, M_k, M_l = miles of highway in each county for each of the three types of highway,
V_j, V_k, V_l = ADT on each type of highway, and
w_s = percentage of traffic in shift s.

Positions remaining for patrolling:

$$X'' = X'_f - \sum_i [\sum_s t_{jsi}/(365 h_s)] \quad (12)$$

where

X'' = number of positions available for patrol less time taken for traffic-related activities,
t_{jsi} = time required to perform traffic-related functions on Interstate highways from Equation 11a during shift s in county i, and
h_s = hours in shift s.

Note: the time is summed over all shifts s and all counties i.
Average miles of patrol per position:

$$\bar{M}_j = \sum_s \sum_i (M_{ji}/f_{jsi})/X'' \quad (13)$$

where

$\bar{M}_j$ = average miles of patrol per position on Interstate highways (j),
M_{ji} = miles of Interstate highway in county i, and
f_{jsi} = reduction in speed because of congestion during shift s in county i (from Equation 3a).

After the average miles of patrol statewide is computed, the number of positions per shift is obtained. This is done by dividing the adjusted miles in each county (adjusted for congestion by shift) by the average miles of patrol statewide as shown in Equation 13. Equations 12 through 14 are shown for Interstate highways. The formulas for computing patrols on other highways are similar and are shown starting with Equation 15.

Patrol positions during shift s in county i:

$$X'_{fsi} = [M_{ji}/(f_{jsi}\bar{M}_j)] + [t_{jsi}/(365 h_s)] \quad (14)$$

where X'_{fsi} is the positions for patrolling Interstate highways in county i during shift s and all other variables have been described earlier.

Two-lane highway patrol:

$$X'' = X'_o - \sum_i [\sum_s (t_{ksi} + t_{lsi})/(365 h_s)] - [\sum_i M_{li}]/\bar{M}_l \quad (15)$$

where

t_{ksi}, t_{lsi} = time required to perform traffic related activity, from Equations 11b and 11c,
M_{li} = miles of low-volume highway in county i, and
$\bar{M}_l$ = average miles of patrol for low-volume highways (must be supplied externally).

Average miles of high-volume two-lane patrol:

$$\bar{M}_k = [\sum_s \sum_i (M_{ki}/f_{ksi})]/X'' \quad (16)$$

Patrolling positions for all two-lane roads:

$$X'_{osi} = [M_{ki}/(f_{ksi}\bar{M}_k)] + [M_{li}/\bar{M}_l] + [(t_{ksi} + t_{lsi})/(365 h_s)] \quad (17)$$

Rural Patrol

Allocation to assist rural law enforcement is based on rural population. The model solves for the number of rural persons per police patrol (state and local combined) and then allocates all rural police on the basis of that rural population. State police are assigned only when there are not sufficient local police. To prevent assignment of all available state police to one county, a maximum number of positions is set for any county. Likewise, negative assignment is possible but not necessarily desired. A minimum number of positions per county controls this.

Estimated rural population per law enforcement patrol:

$$R = \sum_i P_i/(X'_r + \sum_i L_i) \quad (18)$$

where

R = persons per law enforcement patrol,
P_i = rural population in county i, and
L_i = local law enforcement patrols in county i.

Note: for each county, the number of state police patrols is computed per shift from

$$X'_{rsi} = P_i/R - L_i \quad (19)$$

X'_{rsi} is constrained to a minimum and a maximum and then $\sum X'_{rsi}$ is compared with X'_r. If the former is larger, R must be increased. If it is smaller, R is decreased. The computation again is performed.

Once all equivalent positions are allocated, the free time from officers allocated to calls for service is removed according to the percentage of free time originally added. Remaining are those positions allocated to policing and patrolling. These positions also are summed by the three shifts in each county and then summed into districts. The output from a computer program to operate the model is shown in Figure 5.

Adjustment factors:

$$f_d = \sum_s \sum_i [X'_{psi}/(X_{csi} + X'_{psi})] \quad (20a)$$

$$u_{dsi} = f_d(X_{csi} + X'_{psi})/X'_{psi} \quad (20b)$$

Policing and patrolling positions:

$$X'_f = u_{dsi}X'_{fsi} \quad (21a)$$

$$X'_o = u_{dsi}X'_{osi} \quad (21b)$$

$$X'_r = u_{dsi}X'_{rsi} \quad (21c)$$

where

f_d, u_{dsi} = adjustment factors, where f_d is the general statewide factor and u_{dsi} is the factor for each county and shift;

X'_{psi} = adjusted number of positions available for policing and patrolling from Equation 9;

X'_f, X'_o, X'_r = final positions assigned to Interstate, two-lane, and rural patrols; and

X_{csi} = persons assigned to calls for service from Equation 7.

Officers assigned:

$$X_f = X'_f c_s \quad (22)$$

where X_f is officers assigned and c_s is officers per position. (Note: X_o and X_r are solved similarly by substituting X'_o and X'_r for X'_f.)

Adding together administrative support, calls for service, and policing and patrolling for each district yields the number of officers that should be allocated (Figure 6). During this process, the distribution, except for administrative support, has

Available to be allocated 178.9

FOUR-LANE HIGHWAYS

Dist	Total Miles	Positions Per Shift 1st	2nd	3rd	TOT
1	102.0	4.4	4.6	4.6	13.6
2	180.0	8.6	9.8	9.6	28.0
3	204.0	0.0	7.8	7.8	15.6
4	123.0	0.0	4.8	4.8	9.6
TOT	609.0	13.0	27.0	26.8	66.8

OTHER HIGHWAYS

Dist.	Total Miles 2-Lane	Other	Position Per Shift 1st	2nd	3rd	TOT
1	830.0	465.0	2.5	3.5	3.3	9.3
2	240.0	100.0	1.0	1.8	1.7	4.5
3	2140.0	2020.0	0.0	6.9	6.6	13.5
4	1390.0	1335.0	0.0	4.6	4.4	9.0
TOT	4600.0	3920.0	3.5	16.8	16.0	36.3

RURAL LAW ENFORCEMENT

Dist	Local Police	Positions Per Shift 1st	2nd	3rd	TOT
1	38	0.0	0.0	0.0	0.0
2	74	0.0	0.0	0.0	0.0
3	26	0.0	1.5	1.5	3.0
4	27	0.0	.8	.8	1.6
TOT	165	0.0	2.3	2.3	4.6

MANPOWER ALLOCATED

Dist	Positions Per Shift 1st	2nd	3rd	TOT	Total Officers
1	6.9	8.1	7.9	22.9	38.0
2	9.6	11.6	11.3	32.5	53.9
3	0.0	16.2	15.9	32.1	53.3
4	0.0	10.2	10.0	20.2	33.5
TOT	16.5	46.1	45.1	107.7	178.7

Miles of Patrol Per Position

4-Lane	17.3
2-Lane	306.2
Other	6000

Rural Pop./Police Officer 6265

Total Allocated to Patrol 178.7

FIGURE 5 Microcomputer output: rural patrol.

Dist.	Admin. Support	Calls for Service	Police and Patrol	Total Allocation
1	18	33.2	38.0	89.2
2	22	39.8	53.9	115.7
3	10	19.2	53.3	82.5
4	8	20.9	33.5	62.4
Staff	30			
TOT	88	113.2	178.7	379.9

FIGURE 6 Microcomputer output: summary of allocations.

been generated mathematically. Control is exercised through parameters that can be changed to reflect different policing philosophies. For example, greater involvement in handling accidents would result from increasing the average time taken to handle an accident. More emphasis on supporting rural law enforcement is established by assigning a greater percentage of patrolling to this function.

This methodology, although it includes a substantial number of steps, is not complex. It lends itself readily to computer application. For this reason, the Illinois DLE has prepared the program for an Apple II in Applesoft BASIC and will be converting it to an IBM PC XT.

COMPUTER APPLICATION

Overview

The model is run in two programs: FACTOR INPUT and MANPOWER. It requires both parameters and variables. Parameters generally are those values that affect the overall operation of the model. Variables are the base data generally available for each county. A separate program handles initial entries or updating of the parameters and variables. All values are stored permanently; one read-write disk is all that is required to run the entire program. Currently the computer used can handle up to 110 counties and 30 districts. The limitation is the 32,000-byte free storage on the Apple II Plus; recoding to the IBM PC XT will allow a larger base for allocation.

There are 18 sets of parameters that must be entered, including 39 different values. These are summarized as follows:

- Total officers to be allocated
- Number of counties in state
- Number of districts in state
- Manhours per year per officer
- Enforcement time (time per stop in hours)
- Minimum and maximum number of state police patrols per shift (rural)
- Percentage of ADT during each shift
- Maximum response time in minutes for each shift
- Patrol miles per position for other rural roads
- Percentage of patrolling assigned to four-lane and other highways and to rural policing
- Accidents and criminal complaints (percentage handled)
- Accidents (time in hours to handle)
- Accidents (percentage queued during each shift)
- Starting and ending times of each shift
- Shift coverage factor for each shift in each district

All, except the shift coverage factors, apply to the state as a whole. Shift coverage is a binary integer where 1 is coverage and 0 is no coverage. It is considered one parameter even though there are three factors for each district representing each of the three shifts.

Entry of Parameters and Variables

Both the variables and parameters can be entered or changed either by running the program FACTOR INPUT directly or through the main program MANPOWER, which automatically calls FACTOR INPUT. This program then allows the user to enter or change any piece of information in either the parameter or variable data file. The user also can print out the values of either of the files.

Variables represent those values that are used as the data base from which the model derives its computations. Except for the administrative support (overhead), which is shown for each of the districts, all remaining values apply to each of the counties. The variables for the model are as follows:

- Administrative support for each district (k) and central office
- Administrative support for central office
- Accidents for each shift for county i
- Criminal complaints for each shift for county i
- Miles of four-lane, two-lane, and other rural highway for county i
- Two-lane, high-volume, and other rural
- Volume of traffic, expressed in thousands of vehicle miles, on four-lane, two-lane, and other rural for county i
- Rural population for county i
- Area in square miles in county i
- Local law enforcement officers in county i

Entry of data into either the parameter file or the variable file is performed in the same manner. The computer displays a list of parameter or variable names along with the current value of each. When data first are entered, the values are blank. For the variables, except for the first two pages shown on the monitor (number of counties and districts and administrative support), each page shows all variable values for each county number. Individual values may be changed or skipped. Entire pages may be skipped or recalled.

Running the Allocation Model

The operation of the allocation model is controlled by the program MANPOWER. Because of the length and amount of output, a printer must be available. Once the program is started, and there are no changes to parameters or factors, the allocation runs automatically. Computations are made and output generated on the printer. Because of the large number of computations that are made, the program runs on the Apple II at the rate of approximately 4 min for every 10 counties.

Changes can be made to parameters in order to examine the effect of these changes on the allocation. Any changes must be made at the start of the allocation program, and then the entire program is run. Because of the limited space in the computer, such changes must be stored permanently. Only one run is made for each set of parameters. However, when conversion is made to a more powerful microcomputer, the user will be able to establish a range for one or more parameters. The program will automatically generate output for each of the parameters selected.

SUMMARY

More than 3 years have passed since the model first was loaded on the DLE main computer. Numerous runs have been made. The Division of State Police has used it frequently both as a tool for planning and for assignment of newly graduated officers. Other states have expressed an interest in the operation.

Although the model was developed originally for the Illinois DLE and as such is police oriented, it has potentially wider applications. Any agency that serves a large geographical area with suboffices might benefit from using the methodology. For example, highway maintenance operates generally from districts or stations. Some of their work resembles calls for service. Its allocation can be handled stochastically. Likewise, there will be other highway activities that resemble patrol. Remaining personnel can be assigned by using that methodology.

More important, however, has been the transfer of the program to the microcomputer. Applying the model to the personal computer has increased its versatility. It also has shown how the microcomputer can be used to assist in planning assignment of personnel. The computer program and documentation are available to others who are interested.

ACKNOWLEDGMENT

The initial development of the model was a joint effort between the author and George Sweat, Commander, Criminal Intelligence, for the Illinois Department of Law Enforcement. Through his efforts the concepts were organized and tested. Additional acknowledgment is given to the Division of State Police; its recently retired Superintendent, R. Joseph Miller, now with Federal Training Academy; and to Deputy Superintendent William Pierce. They have used the output and made numerous valuable suggestions for its improvement.

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A Procedure to Assess the Macro Impacts of Highway System Improvement and Maintenance Activities

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ABSTRACT

In the highway programming and system evaluation process it is often necessary to assess the overall impacts of various highway improvement and maintenance activities in terms of a set of performance objectives. A procedure is presented for systematic assessment of overall impacts of various highway work activities. The performance objectives considered were system condition, level of service, safety, and energy consumption. The impacts of highway activities on these objectives were assessed on the basis of an empirical approach. The empirically generated results were compared with results derived from an expert opinion poll. A comparison, using the Wilcoxon test, indicated that a poll of expert opinion can generally provide a reasonable approach to the macroassessment of highway impacts.