OPTIMAL DEPLOYMENT OF WILDLIFE LAW ENFORCEMENT AGENTS WITH ANALYSES OF AGENT PRODUCTIVITY

by

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INTRODUCTION

Because contemporary wildlife management embraces the idea that management of humans is as viable an alternative as management of habitats or wild animal populations (Giles 1978), then it follows that the wildlife profession should be concerned with how well it performs activities related to human-management. Management of humans is frequently attempted as is clear from the many laws enacted to protect wildlife. Passage of laws is usually followed by the deployment of enforcement personnel to improve the effectiveness of the law. In England as early as the thirteenth century, extensive warden staffs were employed by the nobility for the purpose of law enforcement (Trench 1965). Seven centuries later, the modern wildlife law enforcement agent, equipped with an automobile, service revolver, radio, and other trappings of technological advancement, is hardly comparable to his predecessor bearing a longbow. However, over the years, few questions have been raised regarding the impact of various wildlife law enforcement techniques and equipment on program effectiveness. Such questions have evolved slowly in an environment in which there has been little need to ask what might constitute enough enforcement or what levels are affordable. Only recently have questions been raised about wildlife law enforcement agent manpower requirements and distribution. In addition, very little is known about the measurement of agent productivity or the factors that affect it. In an age of inflation, tightening budgets, intense public scrutiny, and great demand on wildlife and related resources, the wildlife law enforcement agency is under increasing pressure to advance knowledge in these areas.

McCormick (1969, 1970), Giles et al. (1971), Giles (1974), Morse (1973), and Bavin (1976) have indicated the need for making such improvement in the field of wildlife law enforcement. Giles (1974) pointed to the lack of studies of agents and of factors related to their performance. Also emphasized was the need for improvement of deployment strategies, studies of manpower requirements, and assessment of training and educational standards (Giles et al. 1971). Bavin (1976) stressed the need for improved decision-making directed towards the allocation of manpower and fiscal resources. He stated:

> There has been only limited research dealing with allocation of wildlife law enforcement resources. Most studies have only identified many unsolved problems, however, some have pointed the way toward using the systems analysis approach. <u>Additional research, study, and critical analysis is vitally needed</u> before the question of evaluating wildlife law enforcement performance is resolved (Bavin 1976:5) (Emphasis added).

Beattie (1979), in a survey of U.S. wildlife law enforcement chiefs which evaluated their perceived research needs, found that ''Optimum Deployment of Enforcement Manpower'' received the highest median rank of 12 listed research needs and was the second most mentioned research need, following ''Quantification of Violations''.

The problems confronted by the wildlife law enforcement agencies are similar to those of the urban law enforcement agencies. Although the context of these systems is somewhat different, the overlap and similarity between the two is extensive. Schell et al. (1976) suggested 5 major areas in which research was in critical need including studies of police task assignments, modes of transportation, officer characteristics, deployment strategies, and personnel supervision. It is apparent that the similarities between the 2 enforcement systems extend beyond strictly operational aspects and into the realm of needed, but yet-to-be obtained knowledge.

In wildlife law enforcement systems, there are large expenditures being made to employ and support personnel. At the same time, the manner in which manpower is evaluated and deployed often is based on intuition or political criteria alone rather than on a carefully reasoned choice among a variety of strategies. Consequently, there is a general feeling that alternative methods of manpower evaluation and deployment need to be considered to insure that maximum utility is being obtained from wildlife law enforcement agency expenditures.

To effectively achieve wildlife law enforcement agency goals requires making decisions about how to deploy enforcement manpower quantitatively, spatially, and temporally. Once made, such decisions may never be re-evaluated since it is easily said ''That's how we've always done it'', or other administrative problems may obscure their need for re-evaluation. Nevertheless, frequent changes in management goals and environments demand that deployment decisions be re-evaluated just as frequently on a large-scale, regional basis. As a consequence of the critical nature of these decisions (not only in terms of their location in a decision sequence, but also in terms of their probable impact on the achievement of wildlife agency goals), and as a consequence of the many and varied calls for such research, a research problem can be stated as: What alternative to current methods could be used for determining optimal deployment strategies of wildlife law enforcement manpower? Thus, this study has focused on the achievement of two major research goals:

Research Goal I

> To develop an agent deployment decision-aid system for general use by wildlife law enforcement agencies.

Research Goal II

> To evaluate the relative importance of factors affecting agent productivity.

Research Goal I uses the term ''deployment'' strictly in a spatial and temporal sense. As suggested above, part of the solution to an optimal deployment would include an optimal overall quantity of manpower for an entire agency. However, for the present research to address this aspect would have duplicated a considerable amount of research discussed in LITERATURE REVIEW. Research Goal II was included in this study not only because the knowledge to be gained would have value in itself, but also it would be a valuable complement of Research Goal I.

According to Solmon (1970), relative need is not always considered in wildlife research problem selection and much is done without a clear idea of who will use the results, how the results will be used or *if* the results will be used. The research goals of this project have been formulated with the specific intent that the results be used by wildlife law enforcement administrators as part of their regular decision-making activity. Since the research goals address administrator-stated needs of high importance, it is likely that the results of this research will be applied.

LITERATURE REVIEW

Definitions

Terms often encountered in law enforcement research papers are manpower, allocation, deployment, and distribution. Allocation, distribution, and deployment are used interchangeably in many papers whereas, in others, they have unique meanings. The following interpretations will be adopted in this review:

Manpower Requirements: The total number of persons needed to achieve an optimum level of police services in a locale in terms of effort and efficiency (PRC/Public Management Services 1974; hereafter PRC/PMS 1974).

Manpower Allocation: The overall partitioning of available officers by function (i.e. administration, patrol, support, investigation) (Elliot and Sardino 1971, PRC/PMS 1974).

Manpower Distribution or Deployment: Assignment of a given number of personnel according to chronological and geographical factors as they relate to workload (PRC/PMS 1974).

Some additional definitions which should be discussed at this point include:

Efficiency: A measure of resources use in task performance (President's Commission on Productivity 1965?; hereafter PCP Undated), an input or internal measure (Kakalick and Wildhorn 1971).
Examples- Average percent of patrol force deployed per day, man-hours of patrol per total man-hours available.

Effectiveness: How well performing various tasks fulfills an objective, not necessarily in consideration of inputs (PCP Undated), an output measure of external change (Kakalick and Wildhorn 1971).
Examples-Given an appropriate _a priori_

> specification of desired change, response time per call for assistance, convictions per dollar spent, quality arrest score per enforcement hour.

It is apparent that an efficiency measure can be treated as an effectiveness measure if an objective has been specified in terms of changing efficiency. An example would be to state as an objective the desire to maximize efficiency, such as to maximize the agent-hours of patrol per available agent-hour. In fact, it would seem unusual to measure efficiency without having an implicit objective to be more efficient. Thus, although fairly distinct definitions of these 2 terms can be formulated as above, actual measures of efficiency and effectiveness can be interchangeable. Also, the distinction between efficiency, effectiveness, and productivity is blurred, particularly in law enforcement usage. One definition of productivity (PCP Undated) is that it is the ratio of work produced to resources used, a definition barely distinguishable from the same author's definition of efficiency. According to Webster's New International Dictionary (Second Edition), to be productive is to be <u>effective</u> in bringing something about. In addition, usage of the term productive need not imply any relationship to efficiency or effectiveness and only connote the generation of an output. Therefore, it is most pragmatic to consider efficiency and effectiveness as descriptive of productivity. Thus, in the present study, efficient and effective resource use are interpreted as subsets of a general class of productive behaviors.

Manpower Requirements

Classical methods of setting police department force levels have been based on ratios of police per population or on crime rate. Such ratios fail to account for differences in community standards regarding what is considered adequate police protection (PRC/PMS 1974).

PRC/PMS (1974) suggested that a truly objective manpower requirement rule would require determining the point of diminishing manpower returns from an economic standpoint. This means that in order to decide when to stop adding manpower, it is necessary to know when the marginal cost of doing so equals the marginal benefit gained (in terms of dollars or almost any measure of benefit). However, due to problems in assessing the social and monetary costs of adding to police forces, they stated that it is currently impossible to determine this point of diminishing returns. As an alternative to determining such a point, manpower requirements may be estimated through using weighted variables such as land area, population density, geography, numbers of streets, total street miles, number of pedestrians, amount of industry, age and sex structure of population. PRC/PMS (1974) rejected use of these variables because other studies have yet to show conclusively that a correlation exists between physical and demographic variables and crime. Instead, they suggested as the best method available a workload measurement technique consisting of 4 steps:

1. Identify work units.
2. Calculate average service time per work unit.
3. Estimate the number of work units that can be expected to occur.
4. Multiply to get the total amount of work required.

For example, if the average service time for a patrol unit to handle a traffic accident is 2 hours, and 200 accidents are estimated to occur per month in a certain area, then 400 officer-hours of work is to be done. Therefore, if 1 officer works 160 hours per month, 2.5 officers are needed to handle traffic accidents.

Fullerton (1966) published one of the few descriptions of a quantitative method of setting manpower standards for a wildlife law enforcement agency. He pointed out that the California state personnel board standard called for 1 wildlife officer (hereinafter called ''agent'') for every 7,500 hunting and fishing license sold and that this standard failed to provide a meaningful geographical distribution of agents based on existing field workloads. He called for establishing a manpower standard that would maintain a desired level of compliance with game and fish laws and at the same time take into account the existing geographical differences in workload. Fullerton (1966:360) proposed to do this in the following manner:

1. Establish six regions within the state based on area similarity.
2. Set a standard for an agent's effectiveness in attaining an acceptable level of compliance of laws and regulations using man-days of use in each region as the measure of his effectiveness.

The author's interpretation is that Fullerton intended to determine a ''realistic'' ratio of man-days-use per agent, a ratio that personnel in his agency would consider as a reasonable workload. It is unclear as to how man-days-use could be employed as an effectiveness measure as suggested in (2) above. Fullerton (1966:361) stated that the total number of agents working was divided into the total man-days-use to obtain an average man-days-use per agent for each region. Then an informal survey of supervisors was conducted asking them if they thought patrol was ''adequate'' within their county. He reported that the supervisors in counties having scores above and below the regional average generally felt that agent staffs should be increased or decreased respectively. It was also concluded that a 16% increase in force level was needed to match a predicted increase in resource use of that amount in the next 4 years. The ''adequate'' ratio of man-days-use per agent determined by Fullerton (1966) was not reported.

Burkett (1976) wrote that at least 1 state has established a set of standards for determining the total force level needed. Ratios used in Texas are:

1 supervisor per 9 agents *
1 agent per 50 mile (80.4 km) square land patrol
1 agent per 175,000 population
1 agent per 15,000 acres (6071 ha) of inland water
1 agent per 60,000 acres (24,282 ha) of coastal water
1 agent per 10,000 registered boats

* One agent for each 30 mile (48.3 km) square of land area when the sum of the average deer harvested and turkey harvested per county per year per region exceeds 5000 (do not apply 50 mile (80.4 km) square augmentation when applying this standard).

Burkett's (1976) communication failed to state what the priorities were in this set of criteria, i.e. it is not clear how many agents would be deployed if there were 350,000 people in a 50 mile (km) square tract. Obviously important assumptions have been made regarding a relationship of the deterrence, prevention, or apprehension functions of agents to demographic, geographic, and other factors. Burkett (1976) did not describe how the magnitude of the force-level needs ratios were determined.

Prior to the adoption of manpower standards, workers in Texas (Reed and Thompson 1972) had gone to considerable effort to develop multiple regression models for determining the number of agents to be assigned to their various districts. They found that the agent-hours worked in a county could be predicted from information on county population, numbers of resident hunting license sold, and miles of rural road. These independent variables explained 86% of the variation in the dependent variable, agent-hours worked per county. Quite correctly, Reed and Thompson (1972) concluded that the regression equations could be used to project future manpower requirements if adequate forecasts of the input requirements could be obtained. Most importantly, this conclusion would require that the manpower levels at the time of the study met a set of criteria of adequacy and that the regression equations had been shown to have predictive validity.

However, instead of using the regression models in this manner,the original data were re-inserted into the equations in order to yield county-specific ''estimated hours needed''. Based on the results of comparisons between observed hours worked and the regression predictions, recommendations were made for staffing changes. Apparently these authors were unaware that the difference between the hours estimated in this fashion and the observed hours was not due to any predictive power of the regression model but due to its 14% error. Nevertheless, this study should be noted as an unusual and admirable attempt by a wildlife law enforcement agency to apply quantitative methods in developing decision aids. Unfortunately, their work in this area appears to have been terminated.

Based on this review, the best method to establish manpower requirements for an entire wildlife agency would be to adopt certain methods employed in urban enforcement systems. However, there are many apparent problems in attempting to apply to wildlife law enforcement the techniques of determining the manpower requirements of urban police. One of the major ones is that a crime against a person or his property usually results in a call to a police agency followed by standard recording of the report. In the case of wildlife law enforcement agencies, violations rarely result in a recorded report. Cowles et al. (1978) found that only 20 of 50 states had a standard method of recording citizen reports of violations and only 7 of 50 states listed the wildlife agent's professional affiliation in telephone directories. Assuming that most reports of wildlife law violations by the general public would be made by telephone, then the probability of an observed violation being recorded, nationwide, may be as low as 0.056.

Granted that reported crime is only a fraction of actual victimization rates, urban police administrators at least have an index to trends in crime occurrence. Consequently, many of the methods of setting manpower levels and distributing police officers rely on criteria based on records of calls for service. Until the wildlife law enforcement agency is oriented similarly, those methods will very likely remain inapplicable.

For example, the 4-step workload measurement technique (PRC/PMS 1974) pertains primarily to agencies responding to and recording calls for service. Since many wildlife law enforcement agencies do not record information on calls for service and have no way of estimating how much of their time is spent responding to such calls, this technique would be difficult to apply. However, the basic idea is probably the best method of establishing the overall manpower requirements of a wildlife law enforcement agency. If the average rate at which inspections or other work activities are performed is known, this information, coupled with predicted workload, could be used to compute manpower requirements. A technique combining the 4-step approach with Elliot and Sardino's (1971) manpower formula based on patrol frequency would be of most utility to the wildlife law enforcement agency. In Elliot and Sardino's (1971) method, an administrator would have to decide that an agent should patrol past each point on a route at a certain frequency. For example, a desirable patrol frequency could be to pass all points along the patrol route every other day (i.e. every 16 working hours), traveling at an average of 35 miles (56.3 km) per hour. If a patrol route had 1400 total miles (2253 km), then the following computation could be made:

$$N = c/vT = 2.50 \text{ agents} \qquad (1)$$

where:

N = number of agents needed

c = total miles (or km) of patrollable road

v = average patrol velocity

T = desired patrol frequency (hours per agent)

Cowles (1977) suggested a formula combining the two approaches which could yield the entire wildlife law enforcement manpower needs of a state:

$$N = \sum_{j=1}^{k} \sum_{i=1}^{n} \frac{K_{ij} U_{ij}}{R_{ij}} + \frac{c}{vT} \qquad (2)$$

where: $N, c, v,$ and T are as in (1) and

k = number of regions or districts, $j=1,2,\ldots.k$

n = number of types of users, $i=1,2,\ldots..n$

U = number of man-days-use

R = average rate of inspection

K = proportion of a user population to check

Estimation of manpower needs based on such a formula must assume that the activities of checking users and patrol are mutually exclusive. The number of agents needed to patrol is calculated on the assumption that they do not stop traveling during a complete circuit of the patrol route.

To compute manpower requirements as suggested above for a state wildlife law enforcement agency would most likely result in a recommendation for increased staffing. However, as a result of a 3-year law enforcement national manpower survey initiated by Congressional mandate, it was concluded that higher levels of police staffing have not been consistently associated with improved performance in terms of crime reduction or clearance rates. In the same report it was stated that:

> Although increases in police staffing are fully justifiable . . . improvements in deployment and utilization of existing resources, combined with more active citizen involvement and support, may be as important in improving overall police performance as additional increments of police manpower (Anon. 1978:3) (Emphasis added).

According to this report, provision of additional resources alone without other organizational improvements will not necessarily contribute materially or efficiently to the ultimate objectives of law enforcement. The following statement identifies a final, but important, dimension of the manpower requirement problem:

> However, even if such manpower needs could be established in an objective fashion, they are meaningless unless the manner in which such individuals perform their duties conform to some standard of organizational and functional performance. In short, both manpower requirements and performance standards are inextricably related to each other (PRC/PMS 1974:127).

Thus, the purpose of the present study is to look beyond the manpower requirements question. To be asked to create a better mouse-trap does not necessarily require that the designer build 100 or even 1 mouse-trap. The mouse-trap analagous to the wildlife law enforcement agency's manpower requirements problem has been on the drawing board for many years and merely needs the attention of those most responsible to build and to use it.

In the subsequent review, attention is turned to the less well-understood question of where and when to allocate existing wildlife law enforcement manpower resources.

Manpower Distribution

Reviews of the variety of quantitative methods of manpower distribution in the urban police force are presented by Griffin (1958), Chaiken and Larsen (1971), and Kakalick and Wildhorn (1971). The common methods of distribution fall into 4 major categories - methods based on workload models, queuing models, response time models, and random search models.

Workload models

The initial development of the workload formula for police use was by Wilson and McLaren (1963). Also called the hazard formula, the technique has been most widely used by police departments in spite of its limitations.

This formula uses a variety of indices of enforcement officer workload such as number of reported crimes, number of calls for service of particular types, number of accidents, number of doors and windows to check, number or businesses to check, etc., and computes the proportion of total workload in each patrol area. Cowles et al. (1977) described the workload formula in the context of wildlife management. Given an amount f_{ab} of an area-specific level of a particular workload index (b=1,2, . . Q indices), such as miles of stream to patrol, the region-wide amount F_b, associated with P patrol areas (a=1,2, . . P) is:

$$F_b = \sum_{a=1}^{P} f_{ab} \qquad (3)$$

To determine the workload proportion H_a for each patrol area, a subjective factor, W_b can be assigned to each workload index as:

$$H_a = \frac{\sum_{b=1}^{Q} W_b \dfrac{f_{ab}}{F_b}}{\sum_{b=1}^{Q} W_b} \qquad (4)$$

where:

H_a = the proportion of total manpower to deploy to a specific patrol area (a)

P = number of patrol areas in a region a=1,2,...... P

Q = number of work activities and related workload indices, $b=1,2,\ldots\ldots Q$

f_{ab} = area-specific level of the workload index for activity b

F_b = region-wide total of a specific index

W_b = goal-weighted effectiveness of work activity b

Following computation of workload proportion scores in each patrol area of a region, an optimum strategy would be to deploy agents among the districts in direct proportion to the scores. Given M goals ($j=1,2,\ldots M$), Q work activities ($b=1,2,\ldots Q$) and P patrol areas ($a=1,2,\ldots P$), 6 major steps would be required:

1. Determine the relative importance (O_j) of goals by the Churchman-Ackoff procedure (Churchman and Ackoff 1954) or the paired comparison technique (Thurstone 1927).
2. Determine the relative effectiveness, E_{bj}, of each work activity in achieving each goal.
3. Compute the goal-weighted effectiveness, W_b, of each work activity such that:

$$W_b = \sum_{j=1}^{M} (O_j \times E_{bj}) \qquad (5)$$

4. Determine a measure of, or index to, workload for each work activity.
5. Designate the period during which each work

activity should be performed. This step assumes that deployment plans are desired for L (i=1,2,...L) periods of specified duration. It allows the decision maker to define which activities will be included in the computation for any period. To do so would be important when using an index which does not reflect legal or climatic constraints on work activities. Step 5 indicates the desirability of having data which show temporal variation in workload.

6. Compute the proportion of the available manpower to deploy to each patrol area, H_a, for each planning period by the workload formula (Equation 4).

Assuming the third step has been completed, yielding a vector of goal-weighted activity effectiveness values, $\underline{W} = W_1, W_2, \ldots W_Q$, then, for each period i, standardized goal-weighted activity effectiveness values, SW_{bi}, can be computed as:

$$SW_{bi} = \frac{W_{bi}}{W(max)_i} \qquad (6)$$

$W(max)_i$ is the maximum W_b for the Q or less activities designated to be performed during period i. If a work activity is not to be performed, then it can be assumed that the value of W_b for that activity is equal to 0.0 during that planning period. Consequently, H_{ai}, the proportion of manpower to deploy to patrol area a during period i can be computed as:

$$H_{ai} = \frac{\sum_{b=1}^{Q} SW_{bi} \frac{f_{abi}}{F_{bi}}}{\sum_{b=1}^{Q} SW_{bi}} \qquad (7)$$

According to Griffin (1958) and Chaiken and Larsen (1971), the principal difficulty which confronts all methods of this type is the lack of an objective standard for evaluating the weights of the various work activities. However, neither goal importance nor activity effectiveness in achieving goals are always numbers to be discovered by observation or application of a standard. They are often highly diversified and changeable human expressions, many of which could not be determined by empirical studies alone. Thus, it is the responsibility of decision makers to make such judgments and interpretations on the best available information. The approach proposed by Cowles et al. (1977) provides the wildlife law enforcement administrator with a rational, consistent method for making the necessary judgments.

Kakalick and Wildhorn (1971) and Chaiken and Larsen (1971) listed several other limitations of the workload approach:

1. Workload formulae assume a linear relationship among the factors and do not reflect the nonlinear and interactive characteristics observed in practice.

2. Workload formulae often reflect past conditions rather than current or predicted conditions.

3. Workload formulae attempt to depict a simple deterministic system in which many of the variables are probabilistic.

However, these workers stated that the model's use is superior to pure administrative discretion. The first limitation listed above perhaps could be overcome by future research. The second can be reduced by using regressions for short-term projections, and the third can be studied over a range of probabilities in a simulation mode.

Kakalick and Wildhorn (1971) reported the use in Phoenix of an extension of the workload formula. In their application, the basic workload was defined as the sum of delay, travel, and service times for all calls during a given period in a given area. Cars were deployed in proportion to the fraction of total workload predicted to occur in that period and area. This method was hailed for its use of predicted calls rather than past data, and elapsed time rather than just volume of calls. Kakalick and Wildhorn (1971) pointed out that the Phoenix method failed to assess the preventive function of patrol and that all calls were given the same weight.

Bottoms (1973) described the Shoup-Dosser economic model for total resource allocation which appears to fall in the workload model classification. According to Bottoms (1973), the model is based on 2 assumptions:

1. An officer is equally effective anywhere in the city and all officers are equally effective.
2. Potential effectiveness is the ratio of total felony arrests to police assigned in a district at present.

The objective of the Shoup-Dosser model is to minimize X_o:

$$X_o = \sum_{a=1}^{P} \frac{Z_a}{t_a K_a} \qquad (8)$$

Subject to:

$$\sum_{a=1}^{P} t_a = T \qquad (9)$$

where:

P= number of patrol areas

a= patrol area number

Z_a = average number of crimes per unit time in patrol area a

K_a = effectiveness constant for an agent in patrol area a

t_a = number of officers to be assigned to patrol area a

T= total force size

Bottoms (1973:19) stated that in the above objective function ''where t policemen are assigned to area 1, the average crime rate in that area is reduced to Z_a/tK_a.'' However, when attempting to apply the equation, the units of the solution do not correspond to Bottoms' (1973) definition of crime rate. His description of the units of the effectiveness constant was vague. Reference to Dosser (1964:399), who discussed the assumed Poisson distribution of Z, shows that the assumption is made that as t increases in each patrol area there is ''...a reciprocal proportionality relationship between the police applied and reduction in the mean of the distribution, the proportionality factor being K.'' From this statement it appears that Bottoms was incorrect in defining effectiveness as a ratio of felonies to agents as in assumption (2) above. The units of K must, according to Equation 8, be 1/agent (Olson 1976).

Queuing models

Queuing models are part of the area of operations research in which service systems consist of demand units (customers) waiting in line. The objective of this type of analysis is to assure that the probability of an important call encountering a queue or waiting line is below some threshold or that the average time to wait is below some specified limit (Chaiken and Larsen 1971). Models of this type attempt to account for problems of delays as they relate to travel times, service times, and the irregularity of calls for service. Shumate and Crowther (1966) described this model in detail and stated that a major advantage of the technique is that basic assumptions are more easy to verify, than, for example, those of the random search model. They presented rules for computing estimates of the probability of a certain number of events occurring when the average rate of occurrence per unit time is known, for the probability that a certain number of calls will be in queue when an event occurs, and for the average expected waiting time given the ratio of the inter-arrival gap to the average service time of the event.

Criticism of the queuing models is that they do not prove useful in situations where the rate of calls for service are low (i.e. there are no waiting lines), they do not address the preventive role of patrol, and the specific criteria chosen have not been shown to be related to the performance of the system. To eliminate the third problem, it would be necessary to show that benefits increase as delay times decrease (Chaiken and Larsen 1971).

Response time models

Response time models combine queuing, communication, and processing delays with the total travel time in order to determine how service units should be deployed. Formulae are required that relate specific measures of response time to the number of units on duty, the nature of the geographical region, arrival rates of calls for service, and the service times at the scene of occurrence of an event (Chaiken and Larsen 1971). One of the more sophisticated response time allocation procedures is employed by the St. Louis police department. Their system consists of using exponential smoothing to predict calls for service on an hourly, daily, and weekly basis. This is followed by computation of the number of patrol cars needed to answer 85% of these calls without delay. The computation is based on predicted response times for 8 different types of calls. The number of cars assigned to each district is determined by queuing theory (Kakalick and Wildhorn 1971).

Shortcomings of the method are that it bases the decision on a single criterion and fails to include preventive patrol requirements.

Random search models

Elliot (1968) and Elliot and Sardino (1971) described application of this theory to the preventive-apprehension roles of police patrol and patrol distribution. Random search describes the probability of encountering an event that takes place within a given area by an observer moving continuously in the area. The probability is considered to be a function of a Poisson distribution. As derived by Koopman (1956), the basic formula which computes this probability, P, is:

$$P = 1 - e^{(-qtnv/c)} \qquad (10)$$

where:

q= probability of observing the crime when the crime is in progress

t= time required to execute the crime

n= number of patrol units in the area

v= velocity of patrol unit

c= length of area vulnerable to attack

Elliot (1968), in using burglary as an example, said that two questions must be answered:

1. What size must the patrol be in order to minimize the cost of burglaries to a city?
2. How large can the patrol be such that the total cost of burglaries and patrol is not greater than the present cost?

He derived several formulae to answer these questions based on the rule that:

$$D = \frac{cR}{vT} + NLe^{-t/T} \qquad (11)$$

where: D= total cost (patrol + burglaries)

c= miles of patrollable road

R= cost per night for patrolman and vehicle

N= number of burglaries

L= the average dollar loss per burglary

T= average time required to patrol an area in a random manner

t= time required to execute the crime

v= average velocity of patrol unit

e= base of Naperian logarithms

Cost in this sense would imply a direct, perceived cost since the external costs of fear, crime-induced mental health problems, overall security expenses, etc. would be difficult to quantify.

Howland et al. (1971) discussed use of an inductive approach to modeling search tactics. The basic assumption made was that the searcher relies on feedback to adapt to changes in his environment and that he performs tactical maneuvers to reduce the difference between where he is and where he should be to launch an attack. The approach has the advantage of not requiring limiting assumptions of deductive models such as Elliot and Sardino 's (1971). Howland et al. built their model of submarine tactics where a series of adaptive functions predicted response in behavioral variables which then allowed a trace of the system states. Since the true form of such functions was unknown, they were developed empirically and tested experimentally. Expert judgment, observation during field exercises, and strategic requirements were major sources of information for identification of behavioral variables to which tactical decisions relate. Thus, by observing submarine behavior, predictable patterns of submarine movements and other system states were modeled. Computer-assisted processing to record the system's trajectory (i.e. relative positions of searcher and quarry), to predict adaptive responses in behavioral variables, and in searching for optimal tactics at various system states was required.

Quite apparently this approach requires extensive data on behavioral aspects of system components. A model of submarine movements in relation to a single quarry could be considered a relatively simplistic system. Systems with more interacting components would require proportionately more empirical studies thereby yielding the approach as a rather costly one.

Model Selection

It is of interest to consider the characteristics of the class of systems for which Chaiken and Larsen (1971) said the response time and queuing models were most applicable. The characteristics which they listed were:

> 1. Incidents occur and give rise to calls for service. The time and place of the occurrence cannot be predicted specifically.
>
> 2. Units are dispatched to the scene of the incident in response to the call.
>
> 3. The rapidity with which the unit arrives at the scene has some bearing on the actual or perceived quality of the service (Chaiken and Larsen 1971:21).

As determined by Cowles (1977), the system for which such methods are prescribed does not presently approximate that of the typical wildlife law enforcement agency. However, future wildlife law enforcement systems may have them.

The methods of deployment which seem restricted to systems which rely on calls for service are those of the response time models and queuing models. Even if the wildlife agent was response oriented, information is not readily available on travel, communication, or service times of specific types of calls in order to deploy agents on the basis of the volume of such calls. Although rate of calls may be so low as to preclude a direct application of queuing models to the wildlife agencies, the theory may be applicable when queues of active sportsmen are considered as awaiting service by inspecting wildlife agents (Miller 1976). Although none of the models address all functions, those based on response time or queuing theory are noted for ignoring the potential preventive and deterrent functions of patrol, a major activity of the wildlife agent. Thus, response time and queuing models, as presently formulated, are only slightly applicable to the wildlife law enforcement system.

Random search models address the apprehension role directly and the preventive aspects indirectly. Chaiken and Larsen (1971:45) showed with their model that the probabilities of apprehending felons, even in areas with maximum coverage, were very small, much as was computed for existing police systems. The most limiting aspect of the deductive random search models such as derived by Koopman (1956) is in obtaining values for t, q, (Equation 10) or L (Equation 11). To determine values for t would necessitate specific definition of when violations begin and end. This could be particularly difficult with some of the more common wildlife law violations such as licensing violations, exceeding bag limits, or trespass. Since many such violations do not result in property loss, values for L may not be obtainable either. The inductive, cybernetic search model discussed by Howland et al. (1971) probably has potential for application to wildlife law enforcement if a general model of violator-agent behavior is desired. Data needs for this approach would include extensive empirical studies of field situations. Predictive models of agent behavior would be easiest to obtain. Models of only limited types of violator behavior would be possible to obtain. It would be extremely difficult to obtain reliable models of the behavior of violators under pursuit. As suggested above, the greatest limitation of any type of search model is simply that much of a wildlife law enforcement agent's activity is spent in other modes than searching for violators. To deploy manpower based on these models alone would most likely lead to suboptimal distributions, particularly considering complex and diverse wildlife agency goals.

Of all the methods reviewed, application of the workload formula would seem least likely to be rejected by the wildlife law enforcement administrator and would best meet their needs. Not only can the model address activities with possible preventive and deterrent functions, but also account for many educational and public relations activities. The greatest hurdle would be to obtain data required to describe the various types of agent work on a regional and temporal basis. However, the method is less data intensive than others and the concept of workload indices probably is already embraced to a large extent by enforcement administrators. Most wildlife agencies have ready access to data sources on wildlife resources as indices of various types of agent work in their own files, not to mention readily obtained census and land use data from outside the agency. Since the computational aspects of the workload model are straightforward, a deployment system based on such a model would be required to place emphasis on the weighting of workload indices. Also, to insure use by administrators, not only must the basic algorithm be understandable, but also the system must be able to incorporate their input. The workload model has such characteristics. Therefore, it was selected as a basis for a general use deployment system discussed further in METHODS, Research Goal I.

Cowles et al. (1977) identified an additional dimension to the manpower distribution problem. Since most wildlife law enforcement agents reside permanently in an assigned patrol area, prescribed distribution plans which vary from the permanent distribution would require movement of manpower among patrol areas in order to be implemented. Therefore, an additional decision problem would be created, i.e. the problem of achieving prescribed distributions at least cost. As the number of patrol areas and planning periods under consideration increase, the complexity of the latter problem also increases (perhaps exponentially).

This problem could effectively negate any advantage of workload-based distribution plans if they were provided without guidelines for implementation. Consequently, it was decided that the deployment system should also provide the user with guidelines for distributing manpower at least cost.

Factors Related to Officer Performance

Any decision to move personnel from area i to area j requires either implicit or explicit assumptions regarding the impact of the move on personnel efficiency and effectiveness. One of the primary motivations for moving personnel among patrol areas is to increase effectiveness. According to the national Advisory Group on Productivity in Law Enforcement (1973:2), given the uncertainties of police work, increasing productivity means increasing the probability that a given objective will be met, i.e. increasing the expected effectiveness. They go on to say:

> The clearest example of increasing the probability of achieving intended impact is having personnel assigned when and where crime is highest or calls for service are heaviest. Simple observation can indicate the 'when or where' in general terms; useful analyses of available data can more accurately pinpoint the likely times and places of crime occurrence, thereby significantly increasing the probability of putting officers where they are needed.

However, to reassign all personnel on an equivalent basis in order to increase the probability of achieving intended impact may require at least 2 assumptions:

1. Efficiency and/or effectiveness are not significantly different among agents.

2. Agent efficiency and/or effectiveness are not significantly affected by environmental differences between area i and area j when moved from i to j.

The utility of any decision aid rests in part on such assumptions. Research on factors affecting agent productivity can therefore help to determine the applicability of the workload model. Also, studies on factors affecting agent productivity could lead to an additional input on the workload index weighting process.

Cohen and Chaiken (1972:5) stated that many researchers believe that that the primary influences on a officer's performance are encountered subsequent to employment. If such later influences (socialization, training, environmental characteristics of the area to which assigned) are of more importance, then the relationships observed by many scientists between personal background characteristics and later performance could be artifacts of existing assignment procedures. Nevertheless, there have been many studies attempting to identify relationships between only performance and personal characteristics. In most of the 28 studies of this nature reviewed by the above authors, termination of employment (length of tenure) had been used as a performance criterion. The studies included evaluation of a variety of personality, aptitude, or mechanical tests as predictors of performance. Cohen and Chaiken (1972:15) concluded from their review that :

> 1. Many background variables which would appear logically related to police performance are not valid predictors of performance.
>
> 2. A few psychological and personality tests may be valuable as predictors of very bad performance but they do not appear useful for identifying effective long term performance.
>
> 3. Personal history data (a subset of background variables) show promise as predictors of good and bad performance.

An example of one of the more comprehensive studies of the relationships between officer characteristics and performance was the work of Baehr et al. (1968). Their objective was to develop standards for the selection of patrolmen and to identify distinct patrolman types. The first phase of their research was to perform a concurrent validation study (rather than predictive validation) of a variety of test instruments against several performance measures. In this study (of 242 volunteer Chicago patrolmen) 3 classes of descriptors were measured by questionnaires administered to the patrolmen. These were motivational measures (objective background data, work interest, occupational aspirations), intellectual measures (reasoning, special aptitudes), and behavioral measures (cooperative and temperament traits). The performance measures of the policemen related to these predictors were an internal departmental performance rating (CPD Score), a specialized score determined by the paired comparisons of supervisor ratings, length of tenure, departmental awards, number of departmental disciplinary actions, frequency of sick leave, and the number of arrests. They found that a ''Personal History Index'' was the best predictor of performance, followed by a test of ''Social Insight''. Cross validation studies showed that the tenure criterion was best predicted, then the CPD Score. They concluded that for the battery of tests studied, it was easier to predict how long the patrolmen would work than their actual performance.

An important point regarding this research and a major criticism of it by Gass et al. (1974) was that it was a concurrent validation study, i. e. the battery of tests was only being evaluated in so far as its ability to estimate performance of experienced officers at the time they took the tests. More desirable would be knowledge of the predictive validity of such instruments or measures, i. e. the ability to predict later performance.

Cohen and Chaiken (1972) used a somewhat different approach to analyse the relationships between officer background and performance. They obtained data from application forms of 1915 men hired by the New York City Police Department in 1957. From these data they derived 33 background variables for each man. Also they collected data on 17 performance variables for 1600 of the original 1915 still employed at the time of their study (1968). Thus the study was designed to evaluate the validity of using the background characteristics of job candidates in predicting later job performance. The study design also avoided potential volunteer bias. The analysis of data from a single cohort avoided the variation in administrative policy that would be incurred by different cohorts. The most pertinent results of their study was that the recruit training score was the strongest predictor of later performance. The results of a probationary evaluation and the level of education achieved by an officer were also shown to be good predictors of later performance.

Results of studies such as Baehr et al. (1968), Furcon et al. (1971), and Chaiken and Cohen (1972) indicate that background measures, particularly personal history data, can be useful predictors of officer performance. If certain considerations are made relative to study design (Cohen and Chaiken 1972), the usefulness of such analyses in predicting the performance of job candidates has been demonstrated. Although the merit of duplicating Cohen and Chaiken's (1972) study in a wildlife agency would be considerable, the feasibility of doing so appears rather limited. The wide variety of performance or predictor variables such as available from the NYCPD would not be readily found in most wildlife law enforcement agencies. Small sample sizes combined with a comparatively low turnover rate (or high variance among states if a regional approach were considered) would reduce the potential of duplicating such a study.

As Cohen and Chaiken (1972) suggested, the application and usefulness of such studies would be greater if the importance of other factors, such as working conditions, were known as well.

Ritter (1975) touched briefly on analysis of the relationships of several factors to agent performance. Using district-wide data and regression techniques, he found that district game arrests could be predicted from independent measures of auto miles driven, ranked public relation hours in the previous year, and game enforcement hours. Boat arrests could be predicted by data on boat inspections. On the other hand, when attempting to predict similar productivity criteria for agents (rather than districts), regression analysis revealed no predictive relationships. He concluded:

> Based on these negative conclusions, great variety exists in either warden effectiveness, warden working conditions, or both. My opinion is that the great diversity in counties in which wardens work is mainly responsible for this effect. County differences such as miles of road, area, percentage of rural area, population, and hunting, fishing, and boating pressure all would lead to different working conditions for the wardens . . . Therefore if wardens are to be rated relative to one another, the factors which determine their working conditions must be identified and used as modifiers (Ritter 1975:46).

A useful analytical model would be one which included not only personal characteristics as predictors of performance, but also environmental factors, tactical factors, and variables related to levels of effort. Not only may conclusions related to applicant screening be forthcoming, but also hypotheses regarding the relative importance of relevant factors could be made. Finally, such analyses could lead to an alternative method of weighting of the workload indices that might be used in a deployment strategy.

Due to the need for such research and its relevance to the development of a deployment decision-aid system, the present research also includes a study of factors affecting agent productivity, thereby achieving Research Goal II. The reader is directed to METHODS, Reseach Goal II, for further discussion of this phase of the study.

METHODS

Research Goal I

General Approach

Research Goal I explicitly states an intent to develop a ''general use'' decision-aid system and, thus, this project required attention not only to the conceptual and mathematical form of the system, but also to the needs of the intended user. To maximize the user's effectiveness as a decision maker, a decision aid should:

1. Maximize use of the decision maker's knowledge and professional experience.
2. Minimize time, effort, and cost used in providing system inputs, in data processing, and in interpreting outputs.

These 2 requirements are closely tied. As the decision maker spends less time on administration of a decision-aid system, he can spend more on providing inputs such as evaluations and subjective judgments which require considerable thought, as well as on implementation of the system's prescriptions. Therefore, the development of this decision-aid system was done in a manner which would:

1. Use the workload model as described by Cowles et al. (1977).
2. Facilitate the provision of subjective judg-

ments and evaluations needed as imputs.

3. Minimize the time and effort required for system administration.

4. Maximize the interpretability of outputs.

System Design

Fig. 1 illustrates the WILDSTRAT (WILDLIFE LAW ENFORCEMENT MANPOWER DEPLOYMENT STRATEGIES) SYSTEM as designed in this study. The system consists of an interactive set of 8 computer programs written in Fortran IV. All were written and tested using the computer facilities available at Virginia Polytechnic Institute and State University, Blacksburg, Virginia over the period of September 1976 to March 1979. Five (WILD1, WILD2, WILD4 - WILD6) of the 8 programs generate questionnaires to which wildlife law enforcement administrators respond. The WILD3 program processes information obtained from WILD1 and WILD2 to produce adjusted priority weights of goals. The WILDSTRAT program processes information obtained from WILD1 - WILD5 and from accessory information on workload indices to produce typed summaries of input and manpower distribution plans. The LOWCOST program processes information obtained from WILD6 and WILDSTRAT to produce typed guidelines for achieving the prescriptions of the WILDSTRAT program.

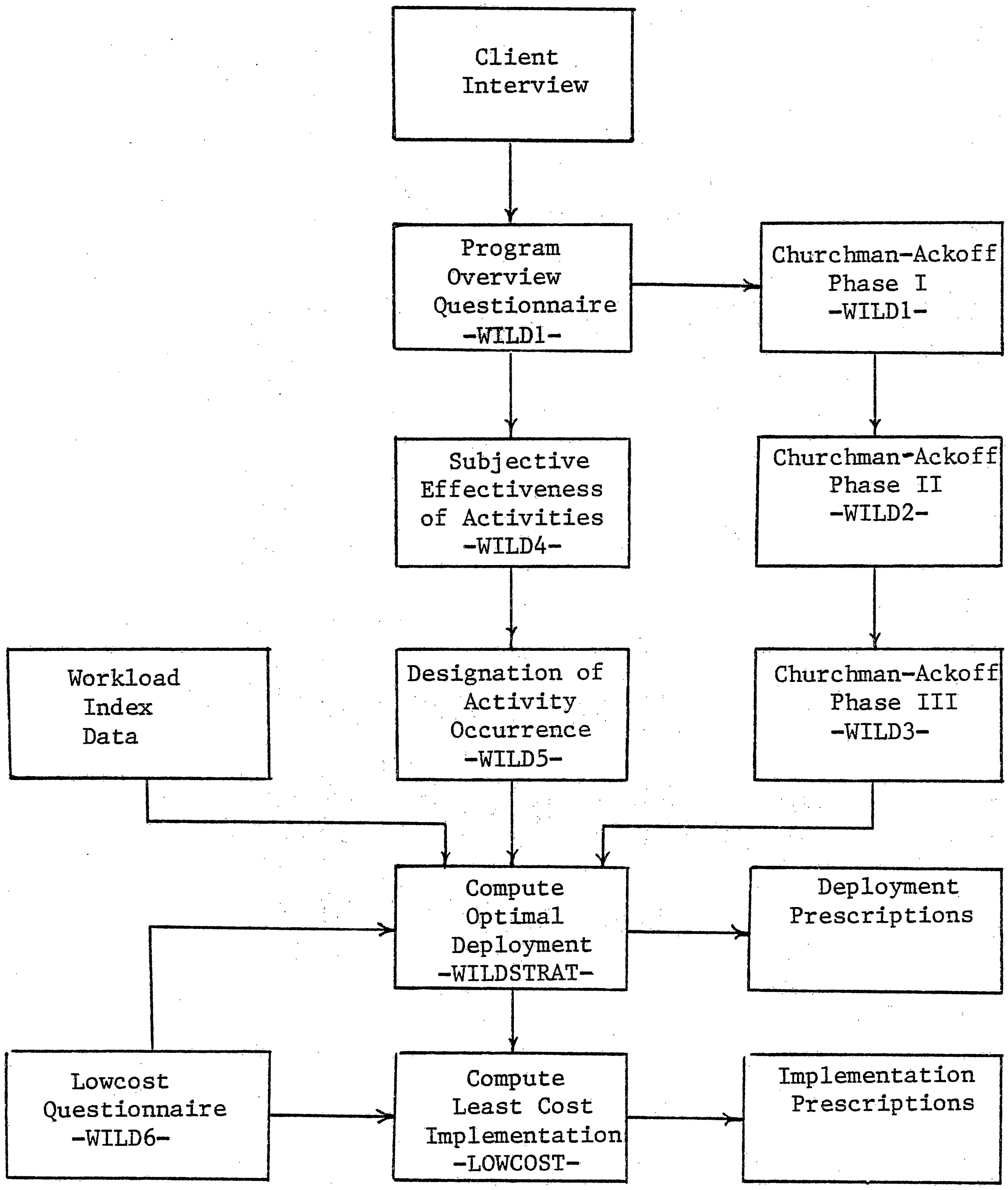

Fig. 1. General overview of the WILDSTRAT SYSTEM.

The programs were written, tested, and documented in approximately the same sequence as illustrated in Fig. 1. Documentation of each program contains 3 sections:

1. Program Description
2. Data Set-up
3. Program Execution

Comments contained in these sections provide the user with information necessary for executing the WILDSTRAT SYSTEM programs on appropriate computational facilities. The programs can be obtained from the Department of Fisheries and Wildlife Sciences, Virginia Polytechnic Institute and State University, Blacksburg, Virginia.

Case Study

In conjunction with design and testing of the WILDSTRAT SYSTEM, a trial application was performed using the J.E.B. Stuart Enforcement District of the Division of Enforcement, Virginia Commission of Game and Inland Fisheries, as a case study. All but one questionnaire were sent to Colonel John H. McLaughlin, Chief, Division of Enforcement, who returned each with his personal responses. The LOWCOST Questionnaire, produced by the WILD6 program, was not sent to Col. McLaughlin because data to be obtained by it had already been received from him in informal interviews. Test data on workload index variables for the

J.E.B. Stuart Enforcement District were obtained from the following sources:

1. McDonald's (1977) MARK IV Virginia County Data, Department of Fisheries and Wildlife Sciences, Virginia Polytechnic Institute and State University, Blacksburg, Virginia
2. POWER SYSTEM, Department of Fisheries and Wildlife Sciences, Virginia Polytechnic Institute and State University, Blacksburg, Virginia
3. VADMIS, Virginia Deer Information System, Department of Fisheries and Wildlife Sciences, Virginia Polytechnic Institute and State University, Blacksburg, Virginia
4. Mr. Herbert E. Gray, Hatchery Section, Virginia Commission of Game and Inland Fisheries, Richmond, Virginia
5. Mr. Larry O. Mohn, Fisheries Biologist, Virginia Commission of Game and Inland Fisheries, Richmond, Virginia
6. Captain J. N. Kerrick, Safety Officer, Virginia Commission of Game and Inland Fisheries, Richmond, Virginia
7. Mr. Sam J. Putt, Chief, Administrative Services, Virginia Commission of Game and Inland Fisheries, Richmond, Virginia

Captain J. H. Eakin, District Supervisor, J.E.B. Stuart Enforcement District, provided information on permanent manpower distributions in that district.

Based on data from the above sources, a complete run of the system was performed. Also, tests of the LOWCOST program as a simulator were made and results evaluated.

Data Collection and Processing

Client interview. On 1 September 1977 a meeting was held with Col. J. H. McLaughlin, Chief, Enforcement Division, at the Virginia Commission of Game and Inland Fisheries in Richmond. The purpose of this meeting was to develop preliminary lists of the Enforcement Division's goals and agent work activities. After discussing and identifying major goals and work activities, inquiries were made of sources of information which could be used as workload indices. Mr. Sam J. Putt, Chief, Administrative Services, provided data on 1976-77 hunting, fishing, and trapping license sales. This was the third meeting with Col. McLaughlin. The previous meetings had been to discuss research proposals.

Program Overview Questionnaire. The objectives of the Program Overview Questionnaire (Appendix 1) were threefold:

1. To permit revision of the preliminary goal list.

2. To permit revision of the preliminary activity list.

3. To perform Phase I of the Churchman-Ackoff (1954) procedure.

The WILD1 program which generates the questionnaire, was written as a simple read/write algorithm where the text of the questionnaire is provided as data for the program. This was done to facilitate modification of the directions and text as needed for future administrations. Objectives 1 and 2 above were achieved by this questionnaire through presenting the preliminary lists of agency goals and activities and soliciting any changes desired by the respondent.

The Churchman-Ackoff (1954) procedure was selected over Thurstone's (1927) paired comparison technique for determining goal importance weights because the former is specifically intended for determining approximate interval scale values of importance from a single respondent. The latter is a statistical procedure which requires a sample of respondents (preferably 30 or more) to develop interval scale measures of psychological response. Thus, it would require more time and expense in administration than the Churchman-Ackoff procedure. Since the deployment system would only incorporate the judgments of a small number of administrators in most applications, the Churchman-Ackoff procedure is more applicable. The procedure has been used in other wildlife and fisheries management applications as well, including Lobdell (1973), Conlin (1975), Clark (1974), and Lee (1973).

The Churchman-Ackoff Procedure consists of 2 phases of data collection and a third computational phase. In Phase I, the respondent orders a set of stimuli; in the present study the stimuli were a set of goals. After ordering the goals, the respondent then assigns subjective scores indicating relative value of each stimulus in reference to the stimulus ranked as the most valued. Typically a score of 100 is assigned to the most valued and other scores assigned relative to it.

The Program Overview Questionnaire (Appendix 1) provided the respondent with necessary directions for performing Phase I of the Churchman-Ackoff procedure. A set of cards called Goal Cards was provided, each card displaying a goal statement and two boxes, one for the respondent to record the rank number and one for recording the subjective score representing the relative value of the goal. The questionnaire was sent to Col. McLaughlin in December 1977.

<u>Churchman-Ackoff Procedure Phase II</u>. Phase II of the Churchman-Ackoff Procedure consists of a series of

comparisons of single goals to ''bundles'' of goals ranked lower. The respondent determines whether the single goal is more important, less important, or equal in importance to the entire bundle to which it is being compared. First, each of the highest ranked (n-2) goals of n goals are compared to a bundle of all other lower ranked goals. Since a bundle must be 2 or more goals, (n-2) comparisons of this nature must be made. Then, if possible, the composition of each bundle is reduced by 1 goal, eliminating the lowest ranked and the comparison made again. This process continues until all possible bundles of 2 or more have been compared. For example, for 5 goals ranked 1-5, the comparisons to be made for goal 1 would be:

1 compared to 2,3,4,5

1 compared to 2,3,4

1 compared to 2,3

Phase III adjustments in goal importance values are made based on the responses to these comparisons. The procedure requires 2 assumptions (Churchman and Ackoff 1954, Morris 1976):

1. It must be possible for the decision maker to think about and judge the value of any combination of stimuli.
2. Values of stimuli are assumed to be additive.

   Given values V_1 and V_2 for 2 stimuli, S_1

and S_2, then the occurrence of S_1 and S_2 together is the sum of $V_1 + V_2$.

The second assumption required the greatest attention in formulating the directions for the Churchman-Ackoff Phase II Questionnaire (Table 1). For the evaluation of goals, it was decided that ''units of achievement'' could be thought of as additive in value rather than the goal statements in themselves. Thus, Table 1 shows directions which specify ''The bundle to the left represents a unit of achievement of the single goal shown and a bundle to the right represents the sum of achievement of a unit of each of the several goals in that bundle''. Although not explicitly stated in the questionnaire directions, implicit in the concept of ''units of achievement'' is that benefits derived from these units are marginal benefits. Thus the goal values are formulated from reference to a existing benefit function. The benefit derived by goal accomplishment is considered as the benefit of the next unit of achievement above and beyond that already sustained, perhaps even in absence of goal achievement.

It is obvious that the better defined the criteria of achievement of goals or objectives, the more closely the second assumption would be met. However, this does not preclude use of the method if well defined criteria do not exist (as might be the case for goal statements) since the

Table 1. Churchman-Ackoff Phase III Questionnaire.

TO: COL. JOHN H. MCLAUGHLIN

RE: GOAL IMPORTANCE SCORE ADJUSTMENT PHASE

FROM: CLEVE COWLES, SOUTHEASTERN WILDLIFE LAW ENFORCEMENT RESEARCH PROJECT

PLEASE FIND ATTACHED A SHORT QUESTIONNAIRE WHICH IS DESIGNED TO REFINE AND ADJUST WHERE NECESSARY THE GOAL SCORES YOU ASSIGNED TO TO EACH OF THE GOALS IDENTIFIED PREVIOUSLY. THE TECHNIQUE EMPLOYED IN THE FOLLOWING QUESTIONS INSURES THAT ALL POSSIBLE COMBINATIONS OF GOALS ARE COMPARED EITHER EXPLICITLY BY THE FOLLOWING COMPARISONS OR IMPLICITLY BY A COMBINATION OF THE COMPARISONS AND THE ORIGINAL GOAL SCORES. AFTER YOU HAVE ANSWERED THE FOLLOWING QUESTIONS, THE ORIGINAL SCORES WILL BE ADJUSTED MECHANICALLY TO MAINTAIN CONSISTENCY WITH THE JUDGMENTS MADE HEREIN.

FOR EACH OF THE QUESTIONS BELOW, ASSUME THAT TWO BUNDLES OF AGENCY GOALS ARE PRESENTED TO THE PUBLIC AND/OR COMMISSION. THE ''BUNDLE'' TO THE LEFT REPRESENTS A UNIT OF ACHIEVEMENT OF THE SINGLE GOAL SHOWN AND A BUNDLE TO THE RIGHT REPRESENTS THE SUM OF ACHIEVEMENT OF ONE UNIT OF EACH OF THE SEVERAL GOALS IN THAT BUNDLE. IF YOU FEEL THAT ACHIEVEMENT OF THE LEFT BUNDLE OF ONE GOAL WOULD BE MORE IMPORTANT THAN ACHIEVEMENT OF THE RIGHT BUNDLE, PLACE A CHECK IN THE SPACE MARKED ''A''. IF YOU FEEL THAT ACHIEVEMENT OF THE RIGHT BUNDLE OF SEVERAL GOALS WOULD BE MORE IMPORTANT THAN ACHIEVEMENT OF THE LEFT BUNDLE, PLACE A CHECK IN THE SPACE MARKED ''B''. IF ACHIEVEMENT OF THE LEFT BUNDLE WOULD BE CONSIDERED EQUAL IN IMPORTANCE TO ACHIEVEMENT OF THE RIGHT BUNDLE, PLACE A MARK IN THE SPACE MARKED ''EQUAL''.

EXAMPLE: CONSIDER THE SITUATION WHERE BUNDLE ''A'' IS ''1. TO PURCHASE A ROLLS-ROYCE.'' AND BUNDLE ''B'' IS ''1. TO PURCHASE A RAMBLER; 2. TO PURCHASE A JEEP.''. IF PURCHASE OF A ROLLS-ROYCE IS CONSIDERED MORE IMPORTANT THAN PURCHASE OF A RAMBLER AND A JEEP, YOU WOULD CHECK SPACE ''A''. IF PURCHASE OF A RAMBLER AND A JEEP WAS MORE IMPORTANT THAN PURCHASE OF A ROLLS-ROYCE, YOU WOULD CHECK BOX ''B''.

PLEASE RECALL THAT THE LONG FORM OF EACH OF THE GOAL STATEMENTS IS:

1. TO ASSURE THAT A DESIRED LEVEL OF RESOURCE USE IS OBTAINED.
2. TO ATTEMPT TO DISTRIBUTE RESOURCE USE OR CONSUMPTION EQUALLY AMONG USERS.
3. TO PROTECT PUBLIC AND PRIVATE PROPERTY FROM HARM AS A RESULT OF RESOURCE USE.
4. TO PROTECT PARTICIPATING RESOURCE USERS FROM PHYSICAL HARM AS A RESULT OF RESOURCE USE ACTIVITY.
5. TO PROTECT NON-RESOURCE USERS FROM PHYSICAL HARM AS A RESULT OF RESOURCE USE ACTIVITY.
6. TO ASSURE AGENCY INCOME BY REQUIRING USERS TO PAY FOR RESOURCE USE.

Table 1. Continued.

PLEASE ANSWER THE COMPARISONS BELOW ACCORDING TO THE ABOVE DIRECTIONS. COL. MCLAUGHLIN

COMPARISON 1

ASSURE AGENCY INCOME

MAINTAIN DESIRED LEVEL OF RESOURCE USE
MAINTAIN EQUAL DISTRIBUTION OF RESOURCE USE
PROTECT PUBLIC AND PRIVATE PROPERTY FROM PHYSICAL HARM
PROTECT RESOURCE USERS FROM PHYSICAL HARM
PROTECT NON-RESOURCE USERS FROM PHYSICAL HARM

A ( ) EQUAL ( ) B ( )

COMPARISON 2

ASSURE AGENCY INCOME

MAINTAIN DESIRED LEVEL OF RESOURCE USE
MAINTAIN EQUAL DISTRIBUTION OF RESOURCE USE
PROTECT PUBLIC AND PRIVATE PROPERTY FROM PHYSICAL HARM
PROTECT RESOURCE USERS FROM PHYSICAL HARM

A ( ) EQUAL ( ) B ( )

COMPARISON 3

ASSURE AGENCY INCOME

MAINTAIN DESIRED LEVEL OF RESOURCE USE
MAINTAIN EQUAL DISTRIBUTION OF RESOURCE USE
PROTECT PUBLIC AND PRIVATE PROPERTY FROM PHYSICAL HARM

A ( ) EQUAL ( ) B ( )

COMPARISON 4

ASSURE AGENCY INCOME

MAINTAIN DESIRED LEVEL OF RESOURCE USE
MAINTAIN EQUAL DISTRIBUTION OF RESOURCE USE

A ( ) EQUAL ( ) B ( )

COMPARISON 5

MAINTAIN DESIRED LEVEL OF RESOURCE USE

MAINTAIN EQUAL DISTRIBUTION OF RESOURCE USE
PROTECT PUBLIC AND PRIVATE PROPERTY FROM PHYSICAL HARM
PROTECT RESOURCE USERS FROM PHYSICAL HARM
PROTECT NON-RESOURCE USERS FROM PHYSICAL HARM

A ( ) EQUAL ( ) B ( )

COMPARISON 6

MAINTAIN DESIRED LEVEL OF RESOURCE USE

MAINTAIN EQUAL DISTRIBUTION OF RESOURCE USE
PROTECT PUBLIC AND PRIVATE PROPERTY FROM PHYSICAL HARM
PROTECT RESOURCE USERS FROM PHYSICAL HARM

A ( ) EQUAL ( ) B ( )

Table 1. Continued.

COL. MCLAUGHLIN

COMPARISON 7

A		B
MAINTAIN DESIRED LEVEL OF RESOURCE USE		MAINTAIN EQUAL DISTRIBUTION OF RESOURCE USE PROTECT PUBLIC AND PRIVATE PROPERTY FROM PHYSICAL HARM
A ( )	EQUAL ( )	B ( )

COMPARISON 8

A		B
MAINTAIN EQUAL DISTRIBUTION OF RESOURCE USE		PROTECT PUBLIC AND PRIVATE PROPERTY FROM PHYSICAL HARM PROTECT RESOURCE USERS FROM PHYSICAL HARM PROTECT NON-RESOURCE USERS FROM PHYSICAL HARM
A ( )	EQUAL ( )	B ( )

COMPARISON 9

A		B
MAINTAIN EQUAL DISTRIBUTION OF RESOURCE USE		PROTECT PUBLIC AND PRIVATE PROPERTY FROM PHYSICAL HARM PROTECT RESOURCE USERS FROM PHYSICAL HARM
A ( )	EQUAL ( )	B ( )

COMPARISON 10

A		B
PROTECT PUBLIC AND PRIVATE PROPERTY FROM PHYSICAL HARM		PROTECT RESOURCE USERS FROM PHYSICAL HARM PROTECT NON-RESOURCE USERS FROM PHYSICAL HARM
A ( )	EQUAL ( )	B ( )

THIS COMPLETES THE QUESTIONNAIRE. THANK YOU FOR YOUR ASSISTANCE.

respondent need only maintain a consistent, self-defined concept of the units of achievement.

The WILD2 program generates the Churchman-Ackoff Phase II Questionnaire. A preliminary version of WILD2 was written by J. M. Lee which was then revised for use in the WILDSTRAT SYSTEM. Table 1 shows the specific instrument to which Col. McLaughlin responded as produced by the WILD2 program. The bundles comparisons shown are a function of the Phase I responses obtained. The questionnaire was sent to Col. McLaughlin in February 1978.

<u>Churchman-Ackoff Procedure Phase III</u>. Phase III of the Churchman-Ackoff Procedure consists of a mathematical adjustment of subjective scores obtained in Phase I in order to maintain their consistency with the Phase II bundle comparisons. Given a set of stimuli, the following adjustments could be made:

If the respondent indicated that S_j was more valued than $S_k, S_l, \ldots S_m$, then the value V_j is adjusted so that $V_j \geq V_k + V_l + \ldots + V_m$.

If the respondent indicated that S_j was less valued than $S_k, S_l, \ldots S_m$, then the value V_j is adjusted so that $V_j \leq V_k + V_l + \ldots + V_m$.

If the respondent indicated that S_j was equal in value to the bundle, than V_j is adjusted so that

$V_j = V_k + V_l + \ldots + V_m$.

According to Morris (1976:172), the method does not suggest a unique value for the adjustment factor so judgment must be applied again. In the WILD3 program, which performs these adjustments, an adjustment factor of $\pm$ 1.0 is added to the bundle value as appropriate and then this sum is assigned as the value of the single goal. The net results are scale values which approximate interval measures of value consistent with all bundle comparisons. The WILD3 program was written to adjust goal importance values for an unlimited number of respondents. The original form of the program was written by William M. Conlin and modified for use in the WILDSTRAT SYSTEM.

Subjective Effectiveness of Activities. The Subjective Effectiveness of Activities Questionnaire, generated by the WILD4 program, has the purpose of developing a matrix of effectiveness scores where each score, E_{bj}, is the subjective effectiveness of activity b in achieving goal j. There were 3 primary concerns addressed in questionnaire directions (Table 2):

1. That a consistent definition of the term ''effectiveness'' be applied throughout the scoring procedure.

Table 2. Directions for Subjective Effectiveness of Activities Questionnaire.

TO: COL. JOHN H. MCLAUGHLIN

FROM: C. J. COWLES, SOUTHEASTERN REGIONAL WILDLIFE LAW ENFORCEMENT RESEARCH PROJECT

RE: SUBJECTIVE ESTIMATION OF THE EFFECTIVENESS OF ACTIVITIES IN ACHIEVING DIVISION GOALS.

ATTACHED IS A QUESTIONNAIRE DESIGNED TO OBTAIN YOUR BEST ESTIMATES OF THE EFFECTIVENESS OF ENFORCEMENT AGENT ACTIVITIES IN ACHIEVING YOUR DIVISION'S GOALS. THE QUESTIONNAIRE CONSISTS OF SEVERAL SECTIONS, EACH SPECIFIC TO ONE OF THE MAJOR ACTIVITIES YOU IDENTIFIED PREVIOUSLY. EACH SECTION PROVIDES SPACE TO RECORD YOUR EVALUATION OF HOW EFFECTIVELY THE ACTIVITY ACHIEVES EACH OF THE PREVIOUSLY IDENTIFIED DIVISION GOALS.

ASSUME THE SCORE OF THE EFFECTIVENESS OF AN ACTIVITY IN ACHIEVING A GOAL CAN RANGE FROM 0 TO 100, WHERE 0 MEANS ''NOT EFFECTIVE AT ALL'' AND 100 MEANS ''VERY EFFECTIVE''. IN THE EXAMPLE BELOW, THE ACTIVITY ''INSPECT BOAT LANDINGS'' HAS BEEN CONSIDERED TO BE OF LOW EFFECTIVENESS IN ACHIEVING GOAL 1 AND THUS A SCORE OF 20 HAS BEEN PLACED IN THE APPROPRIATE SPACE. ON THE OTHER HAND, THE SAME ACTIVITY HAS BEEN CONSIDERED QUITE EFFECTIVE IN ACHIEVING GOAL 2. THUS, A SCORE OF 86 HAS BEEN PLACED IN THE SECOND SPACE. THE SECOND ACTIVITY, ''INSPECT FISHERMEN'', HAS BEEN GIVEN A SCORE OF 60 IN ACHIEVING GOAL 1, BUT IS SHOWN AS MUCH LESS EFFECTIVE IN SERVING TO ACHIEVE GOAL 2.

EXAMPLE:

Table 2. Continued.

ACTIVITY: 1. INSPECT BOAT LANDINGS.

GOALS	EFFECTIVENESS SCORES
1. TO INSURE AGENCY INCOME	20
2. TO PROTECT PUBLIC PROPERTY	86

ACTIVITY: 2. INSPECT FISHERMEN

GOALS	EFFECTIVENESS SCORES
1. TO INSURE AGENCY INCOME	60
2. TO PROTECT PUBLIC PROPERTY	10

Table 2. Continued.

YOUR TASK IS TO ASSIGN EFFECTIVENESS SCORES FOR THE DIVISION'S ACTIVITIES SIMILARLY. YOU SHOULD DO IT IN SUCH A FASHION THAT MEANINGFUL COMPARISONS CAN BE MADE BETWEEN ACTIVITIES, AS WELL AS BETWEEN THE SCORES RELATED TO A SINGLE ACTIVITY. FOR EXAMPLE, THE SCORES ASSIGNED IN THE SAMPLE ABOVE IMPLY THAT ''INSPECT FISHERMEN'' IS MORE EFFECTIVE THAN ''INSPECT BOAT LANDINGS'' IN ACHIEVING A GOAL OF ''TO INSURE AGENCY INCOME'' SINCE THE EFFECTIVENESS SCORES ARE 60 AND 20, RESPECTIVELY. YOU MAY WANT TO RECORD YOUR ANSWERS ON A SEPARATE PAGE OF ROWS AND COLUMNS WITH APPROPRIATE HEADINGS IN ORDER TO MAKE IT EASIER TO MAKE SUCH COMPARISONS.

WHAT IS MEANT BY ACTIVITY ''EFFECTIVENESS'' IN ACHIEVING A GOAL IS A DIFFICULT QUESTION. THE ULTIMATE DEFINITION DEPENDS ON YOU AND/OR YOUR ASSISTANTS, AS DO THE SUBJECTIVE EVALUATIONS. ONE APPROACH MIGHT BE TO CONSIDER ACTIVITY ''EFFECTIVENESS'' AS THE PROBABILITY OR ODDS THAT A SATISFACTORY DEGREE OF GOAL ACHIEVEMENT WOULD BE REALIZED IF ALL AGENTS PERFORMED ONLY THE ACTIVITY BEING EVALUATED. THEREFORE, IN THE EXAMPLE, IF ALL AGENTS ONLY INSPECTED FISHERMEN AND DID NOTHING ELSE, THERE IS A 10 PERCENT CHANCE THAT A SATISFACTORY DEGREE OF PROTECTION OF PUBLIC PROPERTY WOULD BE ACHIEVED.

ANOTHER CONSIDERATION IS THE CASE WHERE YOU BELIEVE THE EFFECTIVENESS SCORE MIGHT DEPEND ON A PARTICULAR GEOGRAPHICAL AREA OR ON THE AMOUNT OF EFFORT EXPENDED ON THE ACTIVITY. TO AVOID THIS DIFFICULTY IN ASSIGNING THE SCORES, YOU WILL HAVE TO MAKE CERTAIN ASSUMPTIONS. FOR EXAMPLE, YOU MAY ASSUME THAT YOU ARE MAKING THESE ESTIMATES BASED ON THE OVERALL ANNUAL PERFORMANCE OF THE ENTIRE AGENT WORK FORCE, OR YOU MAY ASSUME A HYPOTHETICAL ''AVERAGE'' LOCALE EXISTS WHERE EACH ACTIVITY

Table 2. Continued.

WOULD BE PERFORMED BY ONE AGENT FOR ONE DAY. AS FOR THE DEFINITION OF EFFECTIVENESS, THE ACTUAL CONTENT OF THE STANDARDIZING ASSUMPTIONS YOU MAKE IS NOT AS IMPORTANT AS BEING SURE YOU USE THE SAME ASSUMPTIONS AND DEFINITIONS WHEN RESPONDING TO OTHER SECTIONS OF THE QUESTIONNAIRE. PLEASE ATTEMPT TO DO SO.

AFTER READING THESE INSTRUCTIONS, LOOK AT EACH OF THE ACTIVITY STATEMENTS BELOW AND ASSIGN A SCORE (ANYWHERE FROM 0 - 100) REPRESENTING HOW WELL YOU THINK THE ACTIVITY ACHIEVES EACH OF THE GOAL STATEMENTS. DO THIS IN THE MANNER DESCRIBED ABOVE, ATTEMPTING TO MAKE YOUR RESPONSES RELATIVE TO ONE ANOTHER. SINCE THE QUESTIONNAIRE IS LONG, FEEL FREE TO COMPLETE IT IN SEVERAL SESSIONS OR A PAGE OR TWO AT A TIME RATHER THAN TO TRY TO DO IT ALL AT ONE TIME. THIS WILL HELP TO INSURE THAT ALL RESPONSES WERE MADE USING YOUR BEST POSSIBLE JUDGEMENT, UNBIASED BY FATIGUE.

2. That all activities be considered under a consistent set of hypothetical conditions which may affect effectiveness.
3. Assuming a matrix of effectiveness scores, E, of dimension (QxM), that each effectiveness score, E_{bj}, be made relative to all other scores in the bth row and jth column.

The exact definition of ''effectiveness'' was left to the respondent. The directions encourage consistent use of a single definition such as ''The probability that a satisfactory degree of goal achievement would be realized if agents perform X activity and nothing else''. The second concern is related to potential conceptual variability among environments in which activities are thought to occur. The variability from this source would be greater if the opinions of several respondents were pooled to a single matrix of effectiveness scores. Thus, the directions of the questionnaire suggest that the respondent imagine each activity as occurring in a representative average area. The respondent was encouraged to maintain consistent standardizing assumptions of this nature. The third concern can be accomodated by the physical design of the questionnaire and scoring mechanics. Questionnaire format as designed for the WILDSTRAT SYSTEM assures scores relative to one another in any row b of the matrix E. The respondent is encouraged by the directions to record the scores on a separate page to facilitate comparison within a column. The degree of reliability among scores within a column j is therefore directly proportional to the respondent's willingness to make such judgments relative to one another.

The WILD4 program, was written to produce a questionnaire which would allow evaluation of variable numbers of activities and objectives. The questionnaire was sent to Col. McLaughlin in March 1978.

Designation of Activity Occurrence. As discussed in the literature review, the use of index data may not reflect certain constraints on work activities and therefore the decision maker must be provided the option to specify when activities will or will not be performed. The WILD5 program generates the Designation of Activity Occurrence Questionnaire which allows the decision maker to indicate when each activity occurs over an entire year. The questionnaire was designed for such designations over a maximum of 48 planning periods (12 months of 4 quarters or ''weeks'' each) for variable numbers of activities. The user was also provided the option to make designations of activity occurrence for longer, less frequent periods if so desired. Since it is unlikely at this time that wildlife law enforcement agencies maintain workload index data which show daily variation, the quarter month was selected as the shortest planning period necessary.

Directions for this questionnaire (Table 3) were developed so that the respondent's designation of the occurrence of work activities would reflect:

1. Legal or climatic constraints on work activities.
2. Best estimates of when workload would be zero for each activity.

Under ideal circumstances when the decision maker has true workload measures rather than indices for all activities, emphasis of the second item above would be unnecessary and, if included, would possibly lead to suboptimal distributions of manpower. However, since the present state of management information systems in wildlife law enforcement demands widespread use of workload indices, it was necessary to address the second item in the questionnaire directions. This questionnaire was sent to Col. McLaughlin in June 1978.

Workload Index Data Collection. Based on the results of Program Overview Questionnaire, it was possible to formulate a general idea of the workload index data needs. Cowles et al. (1977) stated that variables chosen as workload indices should be as close a representation of the

Table 3. Directions for Designation of Activity Occurrence Questionnaire.

TO: COL. JOHN H. MCLAUGHLIN

FROM: C. J. COWLES, SOUTHEASTERN WILDLIFE LAW ENFORCEMENT RESEARCH PROJECT

RE: SEASONAL ACTIVITY DESIGNATION FOR AGENT DEPLOYMENT SYSTEM

ATTACHED IS A QUESTIONNAIRE DESIGNED TO ALLOW YOU TO DESIGNATE WHEN EACH OF THE MAJOR WILDLIFE AGENT ACTIVITIES NORMALLY SHOULD BE PERFORMED IN ORDER TO MEET YOUR DIVISION'S GOALS. THESE DESIGNATIONS WOULD BE MADE ON THE BASIS OF YOUR AND/OR YOUR IMMEDIATE ASSISTANTS' KNOWLEDGE OF CONSTRAINTS WHICH DICTATE WHEN CERTAIN ACTIVITIES ARE USUALLY IMPOSSIBLE AND WHEN THEY CAN BE REASONABLY PURSUED. EXISTING STATUTES (E. G. HUNTING AND FISHING SEASON DATES), NORMAL TIMES WHEN RESOURCE USERS START AND STOP RECREATIONAL ACTIVITY (E. G. INITIATING AND TERMINATING THE WATER-SKIING SEASON), AND OTHER LIMITING EFFECTS OF SEASON ON AGENT ACTIVITIES ARE EXAMPLES OF SUCH CONSTRAINTS.

AS YOU WILL RECALL, WE WILL EVENTUALLY ASSIGN AN INDEX AS A PROXY MEASURE OF THE ''TRUE'' WORKLOAD FOR EACH ACTIVITY. FOR EXAMPLE, AN INDEX TO THE NUMBER OF DEER HUNTERS TO INSPECT IN A CERTAIN COUNTY COULD BE THE TOTAL LEGAL DEER KILL OF THE PREVIOUS SEASON IN THAT COUNTY. SINCE FOR NEARLY ALL THE LISTED ACTIVITIES WE MUST RELY ON INDICES AS WORKLOAD MEASURES, YOUR DECISION TO DESIGNATE THE OCCURRENCE OF AN ACTIVITY MUST BE BASED ON TWO POINTS:

Table 3. Continued.

1. YOUR BEST ESTIMATE OF WHEN THE ACTIVITY IS FEASIBLE OR INFEASIBLE DUE TO LEGAL OR OTHER CONSTRAINTS. FOR EXAMPLE, IF THERE IS NO DEER SEASON IN JULY, THEN THE AGENT CANNOT BE EXPECTED TO EMPHASIZE INSPECTION OF DEER HUNTERS DURING JULY. AS AN ADMINISTRATOR DIRECTING AGENT ACTIVITIES, A LEGITIMATE CONSTRAINT WOULD BE WHETHER YOU OR YOUR DISTRICT SUPERVISORS WANT THE ACTIVITY TO BE STOPPED OR STRONGLY DE-EMPHASIZED AT CERTAIN TIMES.

2. YOUR BEST ESTIMATE OF WHEN THE AMOUNT OF A CERTAIN TYPE OF WORK IS SO LITTLE AS TO BE APPROXIMATELY ZERO, EVEN IF AN INDEX WOULD NOT EQUAL ZERO AND/OR IS CONSTANT OVER TIME. FOR EXAMPLE, SUPPOSE THE INDEX OF WARMWATER FISHERMAN INSPECTIONS IS ''ACRES OF OPEN WATER'' YET DURING NOVEMBER A VERY SMALL PORTION OF THE AGENTS' TIME WOULD BE SPENT INSPECTING WARMWATER FISHERMEN. IT MAY BE MORE REASONABLE TO ASSUME INSPECTION OF FISHERMEN IN NOVEMBER IS INCLUDED IN THE ACTIVITY ''NONSPECIFIC PATROL OF ENFORCEMENT AREA''. THEREFORE, YOU WOULD NOT INDICATE INSPECTION OF WARMWATER FISHERMEN AS AN ACTIVITY FOR THE MONTH OF NOVEMBER.

IDEALLY IT WOULD BE PREFERABLE TO DESIGNATE ACTIVITY OCCURRENCE ON A DISTRICT BASIS SINCE PATTERNS OF RESOURCE USE OR LEGAL HUNTING/FISHING SEASONS WILL VARY BETWEEN DISTRICTS. FOR THE PURPOSES OF THIS TRIAL OF THE DEPLOYMENT SYSTEM, PLEASE RESPOND TO THE QUESTIONNAIRE IN AN ATTEMPT TO MAKE YOUR DESIGNATIONS AS BROADLY APPLICABLE AS POSSIBLE.

PLEASE LOOK AT THE QUESTIONNAIRE. EACH PAGE REFERS TO ONE OF THE

Table 3. Continued.

MAJOR ACTIVITIES YOU IDENTIFIED PREVIOUSLY. IF THE ACTIVITY LISTED IS ONE WHICH IS OF MAJOR EMPHASIS THROUGHOUT THE YEAR, YOU WOULD CHECK THE SPACE ''_____ ALL YEAR''. IF THE WORK IS OF A SEASONAL NATURE, YOU HAVE THE OPTION TO DESIGNATE ITS OCCURRENCE ON A MONTHLY OR WEEKLY BASIS. IF YOU CHECK THE SPACE ''JANUARY ___'' (OR ANY OTHER MONTHLY DESIGNATION), THE CHECK WILL INDICATE THAT THE WORK WOULD OCCUR THROUGHOUT THAT MONTH. IN OTHER INSTANCES YOU WOULD CHECK THE APPROPRIATE ''WEEK'' (QUARTER OF A MONTH). PLEASE EVALUATE IN THIS FASHION EACH ACTIVITY AS PRECISELY AS IT SEEMS REASONABLE FOR YOU TO DO.

actual work units as possible and be as accurate and reliable as possible. Prior to and concurrent with data collection, it was necessary to make decisions based on these criteria regarding the alignment of workload indices with specific activities. In most cases, these decisions were made prior to data collection. However, as data collection progressed, and as familiarity was gained with its accuracy, reliability, and availability, some original alignments were revised. Since the workload model shows manpower distributions on a proportionate basis, only relative workload levels are required as input. Therefore it was not necessary to be selective in terms of the units of measure specific to the various potential indices.

Because data collection discussed herein was part of a related research effort (see METHODS, Research Goal II), decisions regarding data collection and alignments were made by the author. Under field applications of the WILDSTRAT SYSTEM, the user would be expected to make these decisions.

Indices of workload level in each patrol area (county) of the J.E.B. Stuart Enforcement District were obtained for all work activities. Data collection was completed in August 1978.

Computation of Manpower Distributions. The WILDSTRAT program was written to compute manpower distributions based on information obtained from the WILD1-WILD6 programs, workload index data, and a small amount supplied directly to the program by the user. Program documentation specifies required input formats. Table 4 lists WILDSTRAT program inputs and input sources. The enforcement district name, patrol area names, and number of patrol areas are shown as being obtained from the LOWCOST Questionnaire. In most applications, it would be expected that the system user would know this information without formal administration of the LOWCOST Questionnaire. In situations where implementation guidelines would not be desired, the latter questionnaire would not be administered.

Because it was impossible to anticipate the varied formats and number of variables to be used in future applications of the WILDSTRAT SYSTEM, subroutine INDEXG (for Index Generator) was written to facilitate modification of data-reading formats. Also the subroutine allows creation of index variables as functions of the index data read. Items 14 and 15 (Table 4) must be supplied to describe the nature and number of variables read and created by INDEXG. INDEXG also aligns workload index variables with the desired activity as specified by the user, and, if desired, writes user-supplied descriptions of indices created by INDEXG. The latter

Table 4. WILDSTRAT program required inputs and data sources.

Program Input	Data Source	Source Program
1. Name of client agency	Client interview	WILD1
2. Number of agency goals	Program overview questionnaire	WILD1
3. Number of work activities	Program overview questionnaire	WILD1
4. Number of work activities	Designation of activity occurrence questionnaire	WILD5
5. Planning period description	Designation of activity occurrence questionnaire	WILD5
6. Goal statements	Program overview questionnaire	WILD1
7. Activity descriptions	Program overview questionnaire	WILD1
8. Goal importance values	Churchman/Ackoff Phases I-III	WILD1-WILD3
9. Activity effectiveness values	Subjective effectiveness of activities questionnaire	WILD4
10. Activity occurrence	Designation of activity occurrence questionnaire	WILD5
11. Name of enforcement district	Designation of activity occurrence questionnaire	WILD5

Table 4. Continued.

Program Input	Data Source	Source Program
12. Number of patrol areas	LOWCOST questionnaire	WILD6
13. Patrol area names	LOWCOST questionnaire	WILD6
14. Total number of workload index variables read and created	User	------
15. Descriptions of workload index variables read and created	User	------
16. Alignment specifications of of data variables as workload indices	User	------
17. Special notes describing alignments	User	------
18. Workload index data, by patrol area	User	------

descriptions are optional input to the WILDSTRAT program.

Output of the WILDSTRAT program was designed to consist of the following items:

1. Message to user
2. Input summaries
3. Deployment strategy matrix
    (a) Printed
    (b) Punched to cards or disk
4. Planning period-specific prescriptions.

Item 1 was provided to insure that all user's have sufficient introductory information to interpret successfully the program output. Item 2 was included to provide the user with a check to assure program computations are as desired. Item 3(b) was formatted to be read directly by the LOWCOST program, the matrix must be of (LxP) dimension, each element representing the proportion of manpower to deploy in planning period i to patrol area a. Item 4 was included to associate graphically deployment levels to patrol areas by name, as well as to list in descending order of effectiveness the activities to be performed. One prescription per period is provided.

The WILDSTRAT program was executed to compute deployment strategies for the J.E.B. Stuart Enforcement District using data selected by the investigator for workload indices and Col. McLaughlin's responses to

WILDSTRAT SYSTEM questionnaires.

<u>LOWCOST Questionnaire</u>. The LOWCOST Questionnaire (Appendix 2) was designed to obtain information necessary for input to the LOWCOST program. This questionnaire was not administered as part of the case study because all data relevant to J.E.B. Stuart Enforcement District were provided by other means. It is anticipated that the LOWCOST Questionnaire would be used in future applications of the WILDSTRAT SYSTEM. Program WILD6 was written to generate this questionnaire. As for WILD1, the entire questionnaire text is provided as data to the program in order to facilitate future modifications. As shown in Appendix 2, the LOWCOST Questionnaire was designed to obtain descriptive information such as costs of manpower transfer, map coordinates of central points of patrol areas, and control parameters necessary for execution of the LOWCOST program. These data, in combination with WILDSTRAT program output, are required for the execution of LOWCOST.

<u>Least Cost Deployment</u>. It was decided that the WILDSTRAT SYSTEM should also provide the user with guidelines for directing movements of manpower from a permanent initial

distribution to the temporary prescribed distribution for each planning period. The LOWCOST program was written to provide these guidelines. The program uses a linear programming algorithm for computing manpower allocations which achieve the prescribed distributions at least cost. The problem formulation employed in LOWCOST is as follows:

Minimize $$X_o = \sum_{i=1}^{n} C_i X_i \qquad (12)$$

Subject to:

$$\sum_{i=1}^{n} a_{ki} X_i \leq b_k \quad \text{for all } k \qquad (13)$$

$$\underline{X} \geq 0 \quad \text{for all } i \qquad (14)$$

Where:

X_o = total cost of manpower transfer

n = total number of possible allocations of manpower. Allocations are defined as shifts of personnel (agent-hours) from patrol areas with excess personnel (supply areas) to patrol areas deficient in personnel (demand areas) or the retention of personnel in a patrol area. $i=1,2,\ldots n$

X_i = number of agent-hours in allocation i

$\underline{X}$ = $(1 \times n)$ vector of values X_i

C_i = cost per agent-hour transferred in allocation i

k = total number of constraints

b_k = amount of constraining resource for constraint k

a_{ik} = amount of resource k consumed per agent-hour in allocation i

Table 5 shows an example of the above model for an enforcement district having 3 patrol areas. The rows represent a set of simultaneous linear equations and inequalities, the columns represent unknowns (X_1, X_2, ... X_{10}) in these expressions. X_1, X_5, and X_9 represent unknown amounts of manpower to remain in patrol areas 1, 2, and 3 respectively. X_2, X_3, X_4, X_6, and X_8 represent unknown amounts to shift from patrol areas 1 to 2, 1 to 3, 2 to 1, 2 to 3, 3 to 1, and 3 to 2, respectively. X_{10} represents the unknown total effective agent-hours to be allocated among all areas. The latter quantity will equal the total agent-hours available minus total agent-hours spent in transit between patrol areas. The column labeled B contains the values for all b_k.

The rows labeled S1, S2, and S3 are supply rows, the quantity b_k in each represents a hypothetical total agent-hours available in patrol areas 1, 2, and 3, respectively. The rows labeled D1, D2, and D3 are demand rows, each with hypothetical coefficients for X_{10} which represent the prescribed proportions of the total effective agent-hours to be achieved in patrol areas 1, 2, and 3, respectively. Coefficients shown in columns X_1 to X_9 represent the efficiency of transfering agent-hours from each supply area

Table 5. Example linear programming matrix for minimization of manpower transfer costs. See text.

	Unknown Manpower Transfers										Constraints	
	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}		B
Obj. Func.												
OF	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}		
Supply												
S1	1.0	1.0	1.0								=	40.0
S2				1.0	1.0	1.0					=	40.0
S3							1.0	1.0	1.0		=	40.0
Demand												
D1	1.0			0.9			0.8			-0.4	≥	0.0
D2		0.9			1.0			0.7		-0.4	≥	0.0
D3			0.8			0.7			1.0	-0.2	≥	0.0
Patrol Hrs.												
B	1.0	0.9	0.8	0.9	1.0	0.7	0.8	0.7	1.0	-1.0	=	0.0
Real Var.												
F	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0		≥	120.0

to each demand area. For example, coefficient $S1,X_2$ indicates that for every agent-hour moved from patrol area 1 to patrol area 2, 1 of 40 agent-hours available is taken from patrol area 1. Coefficient $D2,X_2$ indicates that for every agent-hour taken from patrol area 1, only 0.9 hours will be effective time delivered to patrol area 2. The row labeled B sums effective patrol hours allocated and the X_{10} column assures that the optimal solution balances this sum among the areas as desired. The row labeled OF is the objective function, containing cost coefficients (C_i) for each allocation. An iterative procedure, the SIMPLEX algorithm (Shamblin and Stevens 1974), provides a solution to the problem which minimizes the objective function ($X_o = C_1 X_1 + C_2 X_2 ... +C_n X_n$). Row F assures that only real variables ($X_1, X_2, ... X_{10}$) are in the final solution and not artificial variables (formed in the SIMPLEX algorithm).

The matrix illustrated in Table 5 shows all potential allocations among 3 patrol areas. The LOWCOST program was written to reduce this matrix to include only the non-movement variables and potential movements between supply and demand areas in the problem under consideration. Thus, in the hypothetical problem illustrated in Table 5, patrol area 3 is the only supply area, patrol areas 1 and 2 are both shown as requiring increases in manpower. The actual matrix solved by LOWCOST would contain only columns X_1, X_5, X_7, X_8, X_9, X_{10}, and b_k as well as the slack and artificial variables associated with each. All constraint rows would be included. Reduction of the matrix in this fashion was programmed in order to reduce computer storage requirements and execution time. The LOWCOST program builds the matrix in proper form for any problem involving 25 or less patrol areas.

The minimization problem described above is an example of what is commonly called a transportation model, many applications of which have been made in industry. Amick (1966:65), in discussing the evolution of spatial equilibrium model from the transportation model, stated that a major limitation of such analyses is that transfer costs are not included in the majority and that most objective functions are expressed in terms of production costs. The reason for this is that transfer costs of a good reflect economies of scale, as the volume of goods transferred between 2 points increases, the transfer cost per unit volume varies, usually in a non-linear fashion. Since linear programming techniques assume that objective function coefficients are constant over the range of possible values for the real variables, it is obvious why spatial equilibrium models have not included transfer costs. King and Logan (1964), and Judge and Wallace (1958) suggested methods for using linear techniques to solve such problems. In optimizing the location of meat processing plants, King and Logan (1964) used an iterative procedure of adjusting variable processing costs. Their procedure consisted of:

1. Assigning each region a cost coefficient associated with a large processing plant operating at capacity, the lowest possible cost for the region.
2. Comparing costs assigned in (1) to those of the processing volume indicated by a first solution.
3. Revising costs, if necessary, on an economies-of-scale curve to correspond to the first solution processing volume.
4. Solving the problem by linear programming and adjusting coefficients iteratively until no longer necessary to achieve further refinement in the solution.

A similar procedure is incorporated by the LOWCOST algorithm. First, by comparing a permanent distribution of manpower to the desired distribution, the maximum number of available agent-hours which could be moved from any patrol area j to any other patrol area k in order to meet the desired distribution is computed. For the purpose of this discussion, this maximum is called MaxR. If by definition, X'_i is the <u>estimated</u> agent-hours to be in solution for allocation X_i, and if T_i is defined as the total transfer cost for X'_i, then in the primal matrix, a starting value transfer cost per agent-hour, C_i, can be computed as

$$C_i = T_i / X'_i \qquad (15)$$

where X'_i equals MaxR for all i. Since T_i will vary according to the distance between supply and demand points, starting values C_i will not necessarily be equal. This procedure sets the initial transfer cost coefficients at each movement's lowest possible value in the problem. By doing so, the first solution will favor those allocations which are most efficient and which have the lowest transfer costs per agent-hour.

After the first solution is obtained, the LOWCOST algorithm then compares the amount X_i (in solution) to X'_i, from which initial cost coefficients were computed. If $|(X_i - X'_i)| / X'_i$ is greater than 0.01, C_i is recomputed as a function of X_i and the problem is resolved. This procedure is reiterated until an optimal solution is obtained requiring no adjustments in transfer costs. If a value C_i is found to need adjustment, all a_{ki} are recomputed because they also reflect economies of scale. The algorithm was tested by using a a range of values R substituted for MaxR in order to validate that MaxR as defined above would yield optimal solutions.

Of importance in the LOWCOST algorithm is the manner by which cost coefficients are computed. The following assumptions were made regarding manpower movements:

1. Agents have permanent homes in certain patrol areas.
2. Manpower movements are assumed to occur between pre-defined points, the coordinates of which are constant over the entire planning period.
3. Agents must return by the end of each period to their headquartered, permanent patrol area after moving to meet demand elsewhere.
4. Agents can move in 2 manners, overnight and commuting, between supply and demand points.
5. If an agent commutes to a demand area, he must return home at the end of each full work day. He must return to the demand area to complete any partial days of work left unfinished.
6. If an agent travels overnight to a demand patrol area, he must make only 1 round trip per deployment to that area. If the total agent-hours to be deployed from area i to area j exceeds the total agent-hours possible for 1 agent to achieve during

the planning period, more than 1 agent must be deployed.

Costs of manpower shifts were based on the following variable costs:

1. Cost per mile (or km) vehicle expense (excluding operator).
2. Average salary per hour for all agents in district.
3. Daily meal allowance when commuting or overnight.
4. Daily lodging allowance when overnight.

For overnight deployment, total transfer costs, T_i^o, were sum of vehicle cost in transit, agent salary while in transit and all meals and lodging (both in transit and while in patrol at the demand area). Meals and lodging for the entire deployment period were included since these would not be expenses incurred if the agent were patrolling in his home area. On the other hand, salary and vehicle expenses while patrolling in the demand area were not included as transfer costs since they would probably be expended by the agent in his home patrol area even if not deployed elsewhere. Thus, for overnight travel:

$$T_i^o = 2VW_i + (2SW_i/F) + DG + UX_i \qquad (16)$$

where:

T_i^o = total overnight transfer costs for allocation i

V = average cost per mile (km) of vehicle

W_i = miles (km) distance between supply area and demand area central points

S = average salary per hour of agent

F = average vehicle speed in transit, miles (km) per hour

D = integer number of nights lodging required to complete X_i agent-hours in allocation

G = average cost per night lodging

U = average cost per agent-hour for meals, assumed to be constant over range of X_i.

X_i = number of agent-hours in allocation i

In the case of commuter deployment:

$$T_i^c = E(2VW_i + (2SW_i/F)) + UX_i \qquad (17)$$

where: E = integer number of round trips necessary to complete X_i agent-hours of work

Under a given set of conditions, there is a distance where the total cost of commuting would equal the total cost of traveling overnight. Thus, a break-even distance exists which would indicate whether the agent should commute or stay overnight. If the distance the agent must travel would exceed the break-even distance, he would stay overnight to minimize total transfer costs. If the distance the agent must travel would be less than the break-even distance, he would commute to minimize costs. Since at the breakeven distance, W_{bke},

$$T_i^c = T_i^o \qquad (18)$$

it can be shown that

$$W_{bke} = DG/(2(V+S/F)(E-1)) \qquad (19)$$

and under the usual conditions that for any X_i

$$D = E-1 \qquad (20)$$

then

$$W_{bke} = G/2(V+(S/F)) \qquad (21)$$

Therefore, in computing transfer costs, the LOWCOST algorithm checks whether any deployment of agent-hours greater than one full work day exceeds W_{bke}. If it does, total transfer costs are computed as T_i^o, if it does not, total transfer costs are computed as T_i^c. Fig. 2 shows the average cost curves for deployments of 30, 35, and 40 mile deployments where V, S, G, U, and F equal \$0.15, \$5.00, \$16.00, \$0.95, and 45 mph, respectively. These curves were generated under the assumption that there were 6 work days of a 10 hour length each per planning period. Under these conditions, W_{bke} equals 30.6 miles. Note that for each curve there is a sharp increase in transfer cost per agent-hour at

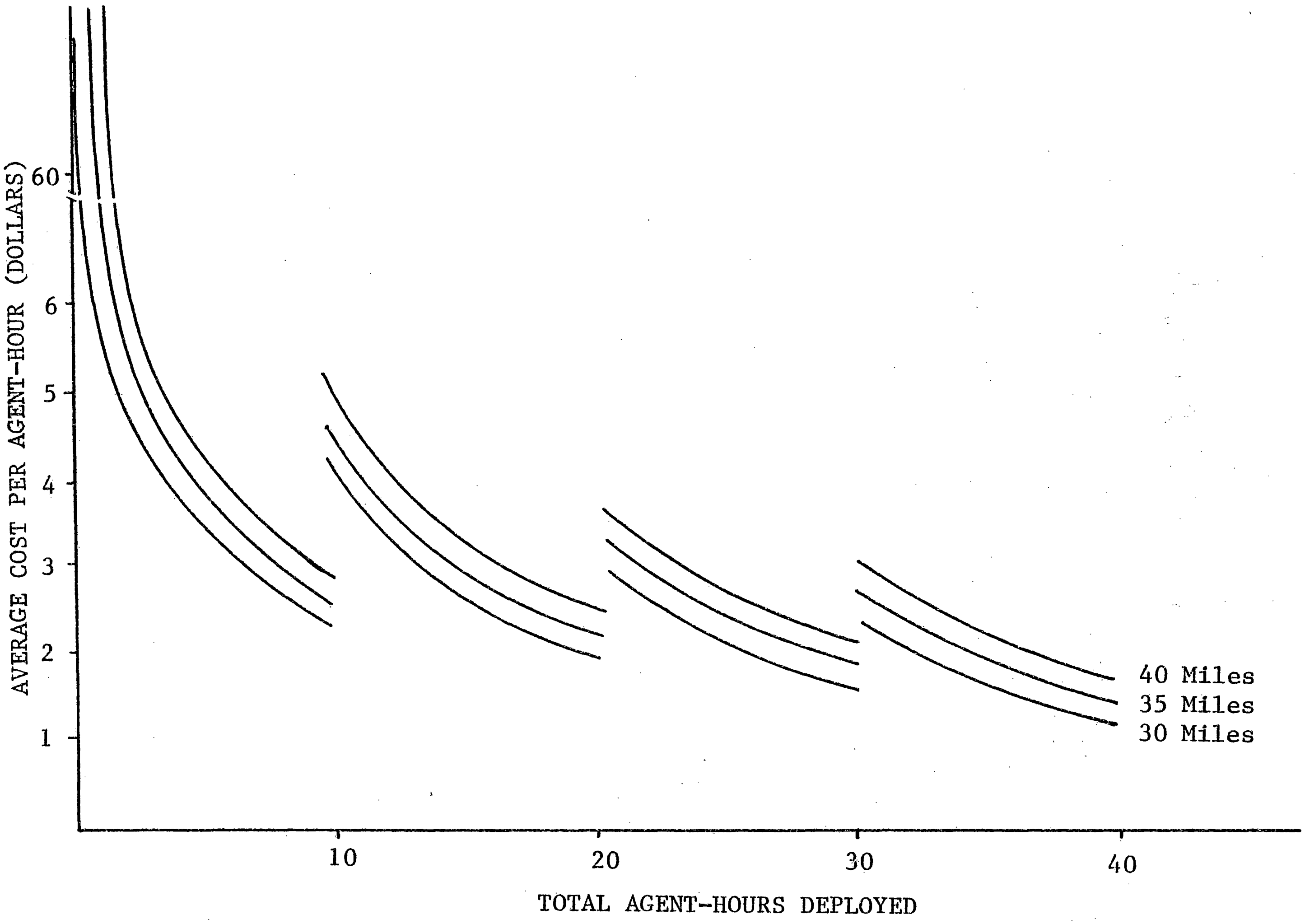

Fig. 2. Average cost per agent-hour as a function of total agent-hours deployed for 3 hypothetical deployments.

the point that X_i exceeds each full work day. This reflects the additional costs of another round-trip for a commuter or additional night's lodging (for the agent whose distance traveled exceeds the break-even distance).

In addition to building the primal matrix, the LOWCOST program was written to automate the computation of transfer costs, matrix coefficients, execution of the SIMPLEX procedure, adjustment of transfer costs and matrix coefficients, re-iteration, and interpretation of the solution matrix. Final output consists of introductory descriptive comments, input data summary, least cost guidelines for deployment implementation, and a job summary over all planning periods under consideration for a particular run. The LOWCOST program facilitates the decision maker's use of it in that execution and interpretation of output require no specialized knowledge of linear programming or linear programming algorithms.

As mentioned earlier, validation runs were performed. Also the program was used to compute least cost movements over 48 planning periods for the J.E.B. Stuart Enforcement District. The program was used to model existing permanent manpower distributions and as a simulator of revised permanent distributions in that district.

Research Goal II

Research Goal II required the accomplishment of 3 objectives:

1. To identify or define a dependent variable by which wildlife law enforcement agent productivity can be measured.
2. To identify or define independent variables useful as predictors of agent productivity.
3. To perform appropriate statistical procedures to evaluate the relative importance of independent variables in explaining variance in the dependent variable.

Objectives 1 - 3 were accomplished concurrently with activities related to Research Goal I. Objective 3, by necessity, was achieved subsequent to the accomplishment of Objectives 1 and 2. Methods for achieving each of these objectives were developed relative to the particular constraints associated with a study of this nature as applied to an existing wildlife law enforcement agency. These methods are discussed below.

The Dependent Variable

Under ideal circumstances, in order to draw conclusions regarding the relative importance of factors affecting agent productivity, a multiple indicator approach to productivity measurement would be most desirable, much as used by Cohen and Chaiken (1972). However, in wildlife law enforcement agencies, the very nature of the degree of independence of the agents has resulted in a lack of formal and reliable productivity measurement. This is not to say that wildlife law enforcement agencies do not attempt to measure agent productivity, but rather that much of the data which is collected is vulnerable to a host of biases. Cowles et al. (1979) discussed one potential measure of effectiveness, a compliance estimate defined as the ratio of arrests to inspections, and found that at least 7 major assumptions must be made regarding use of this estimator. In conjunction with problems related to the usefulness of existing data sources, the wide array of wildlife agent activities suggests there may be need for an equally wide array of productivity measures. However, few of these may be applicable across all wildlife agencies and thus a multivariate approach may limit the degree of generalization possible from an array of productivity measures. However, there is one type of information routinely collected by all wildlife law enforcement agencies which is <u>relatively</u> free of sources of bias and which can be considered an important efficiency or effectiveness measure. This information is arrest data.

Compared to productivity measures such as numbers of inspections or numbers of hunter safety lectures given, arrest data are not as vulnerable to non-report bias or direct manipulation. An arrest made is usually an arrest reported because an agent's ticket book has numbered slips which require documentation detailing the disposition of each case. From a theoretical standpoint, arrest data are perhaps the most important of all productivity measures. Elliot and Sardino (1971) argue that since violation levels are a function of so many other factors than enforcement alone, enforcement activities should focus only on apprehension of criminals and not be concerned with higher-order productivity such as effecting change in compliance rates. Thus, arrest data stand out not only traditionally, but also functionally as extremely important productivity measures in law enforcement. Certainly it can be argued that ''productive'' agents deter or prevent violations and therefore arrest data may not reflect their productivity. But this rationale ignores Elliot and Sardino's point and renders agent productivity nearly impossible to separate from other factors affecting violation rates. Consequently, the present investigator, wanting to draw factual conclusions regarding factors affecting wildlife law enforcement agent productivity; constrained by sources of bias in many data forms; and who strongly believes, in spite of allegations to the contrary, that most enforcement officials use arrest productivity as a major evaluative tool, at present knows of no better measure to select for study of wildlife agent productivity than arrest data.

As many criminologists have stated, numbers of arrests alone do not signify their quality or impact and therefore the usefulness of such numbers as measures of effectiveness of agents in achieving enforcement agency or societal goals is limited. Assuming public service agency goals are established to meet some higher goals of the society within which it exists, then those arrests which best meet agency goals also meet societal goals. Under this assumption, then, a productivity measure acceptable to both an enforcement agency and society would be a quality arrest score (QAS) where quality is a function of the degree to which different types of arrests achieve those goals. Once a set of QAS's was obtained for a group of arrest types, the arrest efficiency (QAS/enforcement hour) or arrest effectiveness (requiring a stated objective to maximize QAS measures) could be determined for each agent.

It was therefore decided that this study would use as a measure of wildlife law enforcement agent productivity a measure of the QAS achieved by each individual in a sample of enforcement agents. The method by which this was accomplished consisted of 4 phases:

1. Development of a violation seriousness scale for a set of wildlife laws.
2. Collection of arrest data from a sample of wildlife law enforcement agents.
3. Conversion of raw arrest data to QAS's.
4. Computation of each agent's enforcement efficiency where efficiency is defined as total QAS per enforcement hour.

Violation Seriousness Scale. The general strategy adopted was to obtain importance weights for 6 enforcement goals, associate the purpose of a wildlife law with a particular goal, acquire subjective evaluations of the relative seriousness of violations in relation to a goal, and to compute goal-weighted seriousness scores for violations of conservation laws. Participants in the study were professional personnel of the Law Enforcement Division of the Virginia Commission of Game and Inland Fisheries. At the time of the survey the division consisted of 87 Officers (Virginia Regular Game Wardens), 27 Sergeants, 12 Lieutenants, 6 Captains, 2 Majors, and 1 Colonel (enforcement chief).

Six enforcement goals were formulated which were considered to be applicable and generalizable to enforcement divisions throughout the United States. These were the same goals used in the case study of the WILDSTRAT

SYSTEM (Research Goal I). The goals were:

1. To assure that a desired level of resource use is obtained.
2. To attempt to distribute resource use or consumption equally among users.
3. To protect public and private property from physical harm as a result of resource use.
4. To protect participating resource users from physical harm.
5. To protect non-resource users from physical harm as a result of resource use activity.
6. To assure agency income by requiring users to pay for resource use.

Scaling of enforcement goals and development of seriousness scores was accomplished in a 2-phase procedure. On 30 June, 1977 Phase I packets were mailed to the 135 individuals of the enforcement division. The packet included a memo from the Chief of Enforcement introducing and approving of the project; a set of instructions for associating the purpose of a law with a goal; 15 paired comparisons (PC) cards (7.62 cm x 12.70 cm), each with 2 goals printed on the card; a listing of the 6 investigator-developed goals and an goal statment labeled "Other"; and, a 4-page (both sides) set of 93 laws to be associated with goals. Thurstone's (1927) PC procedure for scaling perceptions of importance of goals was selected. The PC procedure consists of submitting n(n-1)/2 pairs of n statements to a group of individuals and asking them to make comparative judgments as to which member of each pair is the more important or favorable. Enforcement personnel were requested to place the letters "MI" (for More Important) in the box to the left of the goal which they judged to be the more important of the 2. Certain key words or phrases (e.g. desired level, resource users) included in goal statements were defined in the instructions accompanying the cards packets.

Laws were assigned randomly to page and location on page to remove an ordering effect. The 93 laws listed on the 4 sheets comprised <u>all</u> fish, game, boating, and trapping laws for which 1 or more citations were issued in Virginia between 1 July 1973 and 30 June 1976. Also included in Phase I mailing packets was a self-addressed, postage-paid, return mailing envelope. Respondents were instructed to associate the purpose of a law with a specific goal if they considered more than 50% of the purpose of the law was to contribute to the achievement of a particular goal. If more than 50% of the purpose of a law could not be associated with <u>any</u> single goal, respondents were requested to write the number of the goal labeled "Other" (for other goal(s)) in the box beside the law. Computer-printed follow-up reminders were sent to all enforcement personnel on 10 July 1977.

Thurstone (1927) presented 5 "Cases" or relevant situations appropriate to application of the PC procedure. In scaling the goal-preference data, Thurstone's Case V was assumed. The tenability of this assumption was tested partially using an internal consistency approach described by Edwards (1957).

Responses to Phase I were analyzed prior to development of Phase II materials. Program FREQUENCIES of the Statistical Package for the Social Sciences (SPSS, Nie et al. 1975) was employed to compute the percent of respondents associating a law with a particular goal. A law was operationally associated with a particular goal if 50% or more of the respondents were in agreement about the association of the purpose of the law with a goal. If 50 or more percent concensus was not achieved, the law was placed in a nonspecific goal ("Other") category prior to the second phase.

Since 50 percent or more concensus was not reached on association of any of the 93 laws with goal 5 from Phase I, Phase II goals consisted of 5 specific goals (1,2,3,4,6) and a sixth non-specific goal labelled "Other." In Phase II, "Other" was defined for respondents as "Combined division goals or other goals." Phase II was mailed to personnel on 7 August 1977 and included instructions for completing the materials and 6 different-colored packets of stapled 6.4 cm x 21.6 cm sheets. The top sheet of each packet contained 1 of the 6 goals. Below the goal was an 11-point rating scale, ranging from "NOT SERIOUS AT ALL" to "VERY SERIOUS." In addition to the top goal and rating scale sheet, each packet contained a description of the laws which had been associated with the goal in Phase I. Respondents were instructed to assign subjectively a numerical value reflecting the seriousness of violations of the law in their enforcement district on achievement of the goal. Reference points for the 11-point scale were "NOT SERIOUS AT ALL (1)," "MIDDLE SERIOUSNESS (6)," and "VERY SERIOUS (11)." Respondents were instructed that each of the 11 categories was an equal step on the scale of seriousness. An example related to traffic law enforcement was provided to clarify the procedure for completing the 6 packets. Computer-printed follow-up reminders were sent to personnel 14 days following initial mailing of Phase II materials.

Following return of the Phase II materials, proportion and Z matrices were compiled and interval scale measures of goal importance were computed as described by Edwards (1957). A goal-weighted seriousness score was computed for each law by multiplying the arithmetic mean seriousness score of the law (Phase II) by the Thurstone goal importance (Phase I) of the associated goal. This goal-weighted seriousness score is hereinafter refered to as the

QAS of an arrest made for a violation of the respective law. The reader is directed to a paper by Beattie et al. (1978) for a detailed justification for using the scaling procedure detailed above.

<u>Arrest Data Collection</u>. Arrest data were solicited from essentially the same population of enforcement agents as was used to develop the violation seriousness scale. Summons Data Sheets (Fig. 3) were mailed periodically to these personnel. Each agent was asked to record voluntarily his state radio number and the Virginia Code number of the violation resulting in each arrest made during one of 4 study periods. Other data, discussed later, were also obtained on these sheets. Summons Data Sheets sent directly to the agents were chosen over analysis of data in ticket books because the latter source was inaccessible, and lacked critical information regarding location of arrests. Whether an arrest resulted in a conviction was not determined because conviction rates of wildlife law enforcement agents are typically very high (90% or higher) and closely match their arrest productivity.

Four study periods of 1 month duration each were selected based on <u>a priori</u> knowledge of differences in agent work activities and resource use levels. These

SUMMONS DATA SHEET

PAGE 1

STATE RADIO NUMBER ______ (1 - 3)

MONTH __8__ (11 - 12)

TOTAL ENFORCEMENT HOURS THIS MONTH ______ (13 - 15)

LIST NUMBER	VIRGINIA CODE NUMBER OF VIOLATION	COUNTY ARREST WAS MADE IN	ARREST METHOD* P	S	I	CN	OT	PLEASE DO NOT WRITE IN THE BELOW SPACES	
1.	(16-24)		☐	☐	☐	☐	☐	(25-27)	(28)
2.	(29-37)		☐	☐	☐	☐	☐	(38-40)	(41)
3.	(42-50)		☐	☐	☐	☐	☐	(51-53)	(54)
4.	(55-63)		☐	☐	☐	☐	☐	(64-66)	(67)
5.	(68-76)		☐	☐	☐	☐	☐	(77-79)	(80)
6.	(13-21)		☐	☐	☐	☐	☐	(22-24)	(25)
7.	(26-34)		☐	☐	☐	☐	☐	(35-37)	(38)

* P = PATROL, S = STAKEOUT, I = INVESTIGATION, CN = CITIZEN NOTIFICATION, OT = OTHER
CHECK ONLY ONE BOX

Fig. 3. Partial Summons Data Sheet used to obtain arrest data.

periods were November 1977, and February, May, and August 1978. November is noted for being a month of high hunting activity in Virginia during which several game seasons, including deer season, overlap. February is noted for being a month with relatively little consumptive or nonconsumptive wildlife resource use and of reduced enforcement activity. May is noted for the occurrence of several different types of fishing seasons, particularly spring trout fishing. August is noted for being the peak of the summer boating and warm-water fishing season (Col. McLaughlin, per. comm.). Data collection every month for a 1-year period was considered but was ruled out because it was highly probable that response rates would be negatively related to frequency of data collection. During the last week of the month preceding each of the study periods, Summons Data Sheets were mailed directly to enforcement agents of all ranks. At each mailing, the data sheets were accompanied by a cover letter and a complete set of directions (Appendix 3). The initial cover letter described the purpose of the study, its endorsement by the Enforcement Division, and asked the agent's cooperation. Subsequent cover letters were briefer and focused primarily on minor procedural details. Agents were instructed to submit the completed data sheets at the end of each study period to their District Supervisors. District Supervisors were provided with large, pre-paid return envelopes by which they returned all the data sheets from their district. The same list of addresses was used for each period, with minor changes reflecting address or rank changes. The composition by rank of the recipients of these data sheets was 92 Officers, 31 Sergeants, 13 Lieutenants, 6 Captains, 1 Major, and 1 Colonel for a total of 144 per period. Following receipt of materials from all districts, the raw data were punched exactly as obtained on standard IBM data processing cards.

<u>Conversion of Arrest Data to Quality Arrest Scores</u>. A computer program was written which screened arrest data for each study period and produced a list of Virginia Code numbers detailing the unique types of violations encountered that month. Since November was the initial study period, all violation types were ''new'' that month. In subsequent periods, the list of unique violation codes from the previous period was put into computer storage and only arrest types unique to that list were identified as new. Thus, the list of violation types was incremented as new types appeared in the data. As new types were encountered, each was referenced in Va. Comm. of Game and Inland Fisheries (1973, 1977a, or 1977b) to obtain a written description of the violation. Once this was

accomplished, an attempt was made to match manually this description with one of the law descriptions used as stimuli in the violation seriousness scaling procedure. In most cases, a direct correspondence was obtained. For example, Virginia Code 29-143A was found to have been coded 16 times in the November data. Reference to Va. Comm. of Game and Inland Fisheries (1973:66) showed that statute 29-143A is ''It is unlawful to hunt or kill any wild bird or mammal . . . on Sunday''. Reference to the stimuli presented in the violation seriousness survey showed ''Hunting on Sunday'' as one of the laws evaluated. The violation seriousness score as determined in the seriousness survey was then assigned as a QAS for that type of arrest.

Not all violation types coded were as easily assigned a QAS. On occasion, assignment of QAS was a matter of judgment because exact correspondence between the Virginia Code and violation seriousness survey stimuli could not be found. In general, 4 decision problems were found to occur:

Type 1. Agents did not record the subsection designation of a particular statute, e.g. the ''A'' was not recorded for a violation of type 29-143A.

Type 2. The statute defined more than one type of behavior as a law violation.

Type 3. A direct correspondence could not be found between a Virginia Code statute and a violation seriousness survey stimulus, but a close approximation was found.

Type 4. A direct correspondence could not be found between a Virginia Code statute and a violation seriousness survey stimulus and a close approximation could not be found.

If a Type 1 problem was encountered, the QAS assigned was the mean QAS of all subsections of the statute. For a Type 2 problem, a similar approach was used where the QAS assigned to an arrest of that type was the mean violation seriousness score of the violation seriousness scores of survey stimuli which matched the various behaviors listed in the statute. For example, if a agent listed 29-51 (''It is unlawful to hunt, trap, or fish without a license'') as an arrest made, then the mean of the 3 seriousness scores obtained for the stimuli ''hunting without a license'', ''trapping without a license'', and ''fishing without a license'' was assigned as the QAS for an arrest for violation of Virginia Code 29-51.

Problem Type 3 required the most investigator judgment. For example, arrests for violation of statute 18.2-285 was found to be listed on occassion. This law states that it shall be unlawful for any person to hunt with firearms in the state of Virginia while under the influence of alcohol. None of the stimuli in the violation seriousness survey corresponded directly with this law. However, enforcement personnel were asked to assess the seriousness of the act of operating a boat while intoxicated. The assumption was then made that the two violations would be approximately equal in perceived seriousness and the QAS of the latter stimulus was assigned as the QAS of of an arrest of type 18.2-285.

Problem Type 4 was encountered infrequently. Examples were arrests made for driving an automobile with suspended license (46.1-350), possession of controlled substances (18.2-350), or possession of blackjacks, switchblades, etc. with intent to sell (18.2-311). Due to the relatively infrequent occurrence of such arrests (Table 6), and the limited applicability to wildlife agency goals, these types of violations were assigned a QAS of 0.0.

During the assignment of QAS's to arrests occurring in the November data, the incidence of each type of decision problem was recorded. These records (Table 6) indicated that problems of Type 3 and Type 4 only involved 2.7% and 0.8% of the November arrests. Since these 2 problems were the only ones which involved investigator subjectivity, their extent was of greatest interest. The probable bias

Table 6. A summary of the occurrence of investigator decisions for QAS assignment in November data.

Decision Type	Number of Decisions	Number of Arrests	Percent of Total Arrests
Type 1	6	198	13.2
Type 2	15	580	38.7
Type 3	13	40	2.7
Type 4	6	12	0.8
No Decision Problem	66	668	44.6
Total	106	1498	100.0

for November data resulting from such decisions is shown in Table 6 as being relatively low. Since November had 59.5% of the occurrence of all unique arrest types (106 of 178) encountered, it could be considered a fairly adequate representation of the degree to which such decisions were made in other periods. Records of QAS assignment decision problems were not maintained in subsequent periods.

Following assignment of a QAS to each violation type, the Virginia Code numbers listed in the data were replaced by QAS's for all arrests. A computer program was written to perform this task. Thus, the raw data on arrests were converted from classification level of measurement to an interval measure of quality.

The Independent Variables

A model of wildlife agent productivity was first postulated as:

$$QAS_i = f(P_i, I_i, M_i, S_i, H_i) \qquad (22)$$

where:

QAS = a productivity measure as a function quality arrest score

i = 1,2, ... n observations

P = personal background characteristics

I = environmental attributes of area patrolled

M = enforcement methods

S = study period

H = level of effort

The typical regression model to be used in assessing the relative importance of independent variables such as listed above would be:

$$\underline{Y} = X\underline{B} + \underline{e} \qquad (23)$$

where:

$\underline{Y}$ = a (n x 1) vector of observations

X = a (n x p) matrix of measures on p independent variables

$\underline{B}$ = a (p x 1) vector of parameters

$\underline{e}$ = a (n x 1) vector of errors

In the present study, each observation is a productivity measure in terms of QAS, i.e. QAS/enforcement hour. Elements of the X matrix would represent measured values of a set of independent variables, each postulated as being correlated with the observation on the dependent variable. A major assumption of the model (Equation 23) is that e_i and e_j, $i \neq j$, are uncorrelated and therefore Y_i and Y_j, $i \neq j$, are uncorrelated (Draper and Smith 1966). However, it could be postulated that the productivity of any agent is affected by the effort expended by other agents since their patrol areas may overlap. In this case, the tenability of the latter assumption could be questioned. Consequently, it was decided that for the May and

August study periods data would be obtained which would allow evaluation of the model:

$$QAS_i = f(P_i, I_i, M_i, S_i, H_i, O_i) \qquad (24)$$

where O_i is the level of effort expended by other agents in the patrol area of agent i.

Personal Background Characteristics. Data on personal background characteristics of Virginia wildlife law enforcement agents were obtained from Virginia Application for Employment (G.O. Form P-12) forms submitted by each agent prior to employment by the Enforcement Division. Letters were sent to each agent on 4 April 1978 which explained the purposes for which the information was desired and which asked authorization for use of these forms. Each agent was provided with a postage-paid card to indicate his authorization by signature and asked to return the card directly to the researcher. A follow-up letter was sent to approximately 30 nonrespondents on 18 April 1978. On 10 May 1978 copies of 104 authorizations were sent to the Administrative Services Division of the Virginia Commission of Game and Inland Fisheries requesting release of the applications. Applications authorized for release were received on 26 July 1978. All items were required to be entered on the application form by the job candidate, however, in some cases missing data were encountered. The items listed below were obtained from applications received, variable names used in statistical procedures and later discussion are capitalized.

1. State radio number.
2. Age at application (years), AGEAPP.
3. Length of Virginia residency at application (years), LENRES.
4. Length of active military service (years), MILIYRS.

   If the applicant indicated active duty in the Army, Navy, Air Force, or Coast Guard, years of Reserve duty not credited. If no active duty in Army, Navy, Air Force, or Coast Guard, but Reserve or National Guard experience indicated, 1-year of experience credited.
5. Location flexibility, LOFLEX.

   If application indicated no preferred location, a ''1'' was coded.

   If application indicated a preferred location, a ''2'' was coded.
6. Employment type flexibility, JOFLEX.

   If application indicated temporary employment acceptable, a ''1'' was coded.

   If application indicated temporary employment unacceptable, a ''2'' was coded.

7. Travel flexibility, TRAFLEX.

   If application indicated frequent travel acceptable, a ''1'' was coded.

   If application indicated frequent travel unacceptable, a ''2'' was coded.

8. Flexibility index, FLEXINDX.

   The sum of the codes entered for items 5, 6, and 7 was coded. Thus 4 categories of overall flexibility were established (3, 4, 5, and 6 representing high to low flexibility). This single discrete variable was replaced by dummy variables (FIX1 - FIX3) during regression analyses.

9. Presence of chronic disease (Yes (1) or No (2)), DIS.

10. Sight disorder (Yes (1) or No (2)), SIGHT.

11. Speech disorder (Yes (1) or No (2)), SPE.

12. Hearing disorder (Yes (1) or No (2)), HEAR.

13. Disorder of body or limb (Yes (1) or No (2)), BLIM.

14. Convicted of law violation (Yes (1) or No (2)), CON.

    Minor traffic or game law violations were considered to be convictions.

15. Ever fired (Yes (1) or No (2)), FIRED.

16. Maximum educational attainment at application, EDUC.

One of 14 codes was recorded:

1 - Less than high school

2 - High school

3 - Associate Degree in natural resource field

4 - B.S. in natural resource field

5 - M.S. in natural resource field

6 - Associate Degree in criminal justice field

7 - B.S. in criminal justice field

8 - M.S. in criminal justice field

9 - Associate Degree in other area

10 - B.S. in other area

11 - M.S. in other area

12 - Vocational in natural resource field

13 - Vocational in criminal justice field

14 - Vocational in other area

If the applicant indicated less than 2 years of college, an appropriate vocational category was assigned. If more than 2 years of college but less than 4 years of college indicated, an appropriate Associate Degree category was assigned. No educational credit was given correspondence or military training schools. Due to low frequencies for certain categories, 6 classifications (Less Than High School, High School, Vocational, Associate Degree, B.S., and M.S) were re-coded and dummy variables (ED1 - ED5) created during regression analyses.

17. Work experience diversity, EXPERDIV.
Number of unique full-time positions held for more than 9 months, including military. Unique positions were considered those whose duties and responsibilities were readily distinguishable from all others listed.

18. Years of work experience, YRSEXP.
Total number of years of previous work experience in all full-time positions of 9 or more months duration.

19. Previous enforcement experience (years), PREVENF.
Number of years in full-time law enforcement capacity, including military police if applicable.

20. Number of different positions, DIFFPOS.
Number of different full-time positions, regardless of uniqueness, held for 9 months or more.

21. Licensed fisherman (Yes (1) or No (2)), FISH.

22. Licensed hunter (Yes (1) or No (2)), HUNT.

All variables with only two classifications were converted to dummy variables in regression analyses by re-coding 2's to 0's. In addition to the data listed above, the following information was collected independently of the application forms and entered in the personal background profile of each agent:

23. Rank as of July 1978, RANK.

    One of 5 classifications was coded, Officer (1), Sergeant (2), Lieutenant (3), Captain (4), or Major and/or Colonel (5). Dummy variables R1-R4 were created for regression analyses.

24. Age at employment (years), AGEHIRE.

25. Length of service to July 1978 (months), MOSERV.

State radio numbers were used to align each measure of arrest productivity with personal background data.

<u>Environmental</u> <u>Attributes</u>. Two work environments were defined for each agent, the arrest area designated as that area including all counties in which the agent made arrests during the study period, and the patrol area designated as that area including all counties in which the agent performed enforcement activities, regardless of whether arrests were made. Since an arrest area does not exist for agents who make no arrests, those agents must be dropped

from an analysis using arrest area characteristics as independent variables. This would limit the generalization of any conclusions to only agents who make arrests. Therefore patrol area characteristics are more desirable than arrest area characteristics as independent variables.

It was determined that the Summons Data Sheets (Fig. 3) did not provide enough information for definition of patrol areas, and, therefore, for the May and August study periods, agents were asked to complete an additional data sheet asking them to list all counties of enforcement activity. Instructions for the latter data sheet (County of Enforcement Activity Data Sheet) are shown in Appendix 4. Upon receipt of these sheets, each county listed was given a code (FIPS) number and the codes were recorded on IBM cards. Concurrently, a computer program was written which screened the FIPS codes of counties listed on the Summons Data Sheets in order to produce, by agent, lists of counties comprising arrest areas. Thus, for the May and August study periods patrol areas and arrest areas were defined for each agent. For the November and February study periods only arrest areas could be defined.

Data sources listed in METHODS, Research Goal I, were used to obtain measures of environmental attributes of Virginia counties. All measures were obtained as, or converted (in the case of POWER system data) to county-wide statistics. A program was written which, by agent, computed the per-acre intensity (I) of each of a variety of environmental attributes. These measures of intensity for patrol area environmental attributes were computed for all attributes, by agent, by study period, as:

$$I^{P}_{ijk} = \frac{\sum_{l=1}^{p} E_{jl}}{\sum_{l=1}^{p} A_{l}} \qquad (25)$$

where:

I^{P} = patrol area attribute intensity

E = measured level of environmental attribute per county

i = 1,2, ... n observations

j = 1,2, ... m environmental attributes

k = 1,2, ... o study periods

l = 1,2, ... p counties in patrol area ik

A = county acreage

Similarly, I^{A}_{ijk} was computed for all i, j, and k by the same expression where E, A, i, j, and k were as above and:

I^{A} = arrest area attribute intensity

l = 1,2, ... p counties in arrest area ik

The following environmental attributes or postulated attribute indices were considered as independent variables and appropriate data collected. Variable names are shown as capitalized.

1. Total statewide and county trapping license sales, 1976, TOTRP.
2. Total fatal and non-fatal hunting accidents investigated, 1961-77, HUACCI.
3. Total county acreage, TOTAC.
4. Acres of native and stockable trout water, ACTRTWA.
5. Average legal spring turkey harvest, 1967-77, AVSPTK.
6. Average legal fall turkey harvest, 1967-77, AVFATK.
7. Average legal bear harvest, 1967-77, AVBRHV.
8. Average legal deer harvest, 1967-77, AVDEHV.
9. Total human population, U.S. Census estimate, 1975, TOTHU.
10. Total farms, 1969, TOTFA.
11. Total acres of cropland, 1969, ACCPL.
12. Total acres of harvestable cropland, 1969, ACHVCPL.
13. Total commercial forest, 1976, COMMERF.
14. Total commercial oak forest, 1976, OAK.
15. Number of trout stocked, 1977-78, TRTSTK77.
16. Number of trout stocking trips, 1977-78, STKTRP77.
17. Total POWER system grid cells showing presence of existing and proposed waterfront recreation sites

and boat ramps, TOWAREC.

18. Total POWER system grid cells showing presence of state game management lands, GMNGT.
19. Total POWER system grid cells showing presence of state or federal game management and wildlife refuge lands, TOREFU.
20. Total enforcement hours worked by other agents, TOTOTHHR.

All county measures listed above were identified by FIPS codes. A computer program was written which processed data from County of Enforcement Activity Data Sheets and Summons Data Sheets to produce per county statistics on total enforcement hours worked by other agents (TOTOTHHR) in each agent's patrol and arrest areas. First, the program summed across all agents for each planning period to yield total enforcement hours per county. Then, for each patrol area defined in May and August, the agent's total enforcement hours was subtracted from the overall total for all counties in the Patrol Area. The difference was divided by the patrol area total acreage to yield a per acre (0.4047 ha) intensity of total enforcement hours worked by other agents. This variable, TOTOTHHR, was used to represent O in Equation 24. All other variables (Nos. 1-19, above) were used to represent I in the same model.

Following computation of I^{A}_{jkl} for <u>all</u> study periods, and I^{P}_{jkl} for May and August study periods, simple linear regression was used to develop predictive models which would predict I^{P}_{jkl} for November and February. This was necessary because county lists defining patrol areas were not obtained during the latter months. These predictive models were developed from May and August data and were of the form:

$$I^{P}_{ijk} = f(I^{A}_{ijk}) \qquad (26)$$

Then, values for I^{A}_{jkl} from November and February were substituted to predict patrol area intensities for those periods. These predictions were not done for variables whose predictive models had R^2 less than 0.50 which applied to only 1 variable, total state and federal wildlife management and refuge areas. Total other enforcement hours could not be predicted for November and February because those measures were not obtained for arrest areas in those study periods.

<u>Methods of Enforcement</u>. Summons Data Sheets were completed by agents as instructed (Appendix 3) to classify each arrest by 1 of 4 specific methods or a fifth ''Other'' classification. The methods categories were defined as below:

1. Patrol - Arrest made during random movement or movement of predetermined pattern through the agent's enforcement area. Inspections and subsequent arrests were made incidental to this movement. The arrest was not made as a result of any prior information the agent received which would direct the agent to a specific site, violation, or violator. However, the agent may have patrolled the area because the agent anticipated general resource use and potential violations in that area.

2. Stakeout - Arrest was made as a result of observation of an area while immobile and possibly concealed. Instead of moving through an area, the agent has remained motionless and let potential violators come to him. The agent was staked-out in that area because he had anticipated general resource use and/or potential violation activity at that location. The arrest was not made as an immediate result of prior information supplied by citizens or an investigation which directed the agent to a specific violation or violator.

3. Investigation - Arrest was made as a result of

analysis of detailed information obtained primarily through effort initiated by the officer. The effort usually involved the analysis of a variety of evidence obtained by the officer which subsequently led to the arrest of a specific violator (although the identity of the violator may not have been known until the arrest was made). This does not include response to a single call directing the agent to the scene of a violation - See below.

4. Response to Citizen Notification - Arrest was made following the receipt of a notification initiated by a citizen and perhaps transferred to the officer by a dispatcher or other agent. Following receipt of such a message, the agent went to the scene and the arrest resulted shortly thereafter. The citizen's notification could have been made by telephone, in some written form, or in a direct conversation. The important discriminating characteristic of this method is that a specific message was originally submitted to law enforcement agents by a citizen and there was a response to this specific notification. An arrest resulting from a message supplied by an informant would also

be considered a citizen notification.

5. Other - This classification would be applied only to arrests which were made in some unusual method other than those described above. For example, while off duty a violation occurred near the agent's home, the agent observed the violation, and made an arrest. It was not made during patrol, following an investigation, as a result of a notification, or during a stake-out and thus would be considered ''Other''.

A program was written which processed data from the Summons Data Sheets to compute total QAS by enforcement method for each agent. The latter variables TQSP, TQSS, TQSI, TQSCN, and TQSO, respectively, were used to represent M in Equation 24. Statistical models using percent of total QAS by enforcement method (PCTP, PCTS, PCTI, PCTCN, PCTO) were also analyzed.

Study Period. Each observation was classified as having occurred in 1 of 4 study periods, November 1977, February, May, and August 1978. These classifications represented S in Equation 24. Dummy variables M1-M3 were created to represent effects due to study period in regression models.

Effort. Agents were instructed to enter on Summons Data Sheets the number of hours spent in enforcement activities during each study period. As instructed (Appendix 3), this measure of effort was not to include time spent in other activities such as public relations work. Total hours of enforcement work (TOTHRS) was used as the independent variable representing H in Equation 24 and in computing the efficiency measure used as the dependent variable, QAS/enforcement hour.

Data Analysis

Data analysis with the intent to assess the relative importance of independent variables in explaining variance in the dependent variable was performed in a 3-stage manner. First, the OSIRIS (Institute of Social Research 1973) Automatic Interaction Detection (AID3) algorithm was used to identify potential interactions among independent variables. Second, stepwise multiple regression models were built to screen all variables measured on an interval scale (metric variables) and interactions previously identified. Third, variables entering stepwise models were analyzed as covariates in models which included discrete variables as well.

<u>Automatic</u> <u>Interaction</u> <u>Detection</u>. The theory and application of the AID3 algorithm were discussed in detail by Sonquist et al. (1973). By searching through all possible dichotomous splits between classes of discrete independent variables, the algorithm divides a group of observations according to the variable and division which maximizes the between groups sum of squares on the dependent variable. After each division, the resultant subgroups are re-examined over all independent variables and divided again as described above. The user of the program specifies control parameters which determine the manner in which the splits are performed and terminated. The program output allows the researcher to diagram the dividing process and analysis of the resultant tree diagram facilitates identification of interactions. An alternative approach to accounting for interaction in multiple regression models is to build all possible interaction terms and include them in the model under test, i.e. to test a saturated model. Use of AID3 for <u>a priori</u> identification of interaction eliminated the need to build and test saturated models.

The AID3 algorithm was designed to allow detection of interaction for variables measured at classification level only. Thus, all independent variables which were measured on an interval scale were converted to classification data for AID3 runs. A computer program was written which for each value of an independent variable measured on an interval scale assigned a classification code of 1, 2, 3, 4, 5, or 6. The program identified minimum and maximum values for each variable, divided the range from minimum to maximum into 6 equal intervals and assigned the appropriate classification code in place of the interval measure. This was done for all independent variables not coded originally as classification data.

In order to maintain as large sample sizes as possible for the AID3 runs, the following procedure was used:

1. Search for interactions among all environmental attributes, including total other enforcement hours. Potentially important interactors to be identified according to their order of entry into the model and whether the split on the variable resulted in $n \geq 15$ in at least 1 subgroup.
2. Search for interactions among all personal background variables. Identify important interactors according to criteria stated in (1).
3. Search for interactions among all enforcement methods variables. Identify important interactors according to criteria stated in (1).
4. Search for interactions among important independent variables identified in runs 1, 2, 3 above, total

enforcement hours, and study period.

Regression Analyses. Following *a priori* interaction detection as described above, stepwise multiple regression was used to screen through all metric independent variables (environmental attributes, effort, certain personal background, and interactions) in order to identify those to be entered in analysis of covariance models. Those metric variables which entered the stepwise regressions were entered with discrete variables (study period, some personal background) and interaction terms in the analysis of covariance models. Analysis of covariance was accomplished by multiple regression procedures as provided by SAS (Barr et al. 1976).

RESULTS AND DISCUSSION

Research Goal I

Program Overview Questionnaire

No additions or deletions were made by Col. McLaughlin in the tentative list of goals presented in this questionnaire (Appendix 1). Three additional activities were listed. Thus, 6 goal statements and 25 major work activities (Table 7) were identified and designated for use in the case-study application of the WILDSTRAT SYSTEM.

Subjective importance scores assigned to goals during Phase I of the Churchman-Ackoff procedure are shown in Table 8, column 2. ''Assure Agency Income'' ''Maintain Desired Level of Resource Use'' were ranked 1 and 2 and assigned nearly equivalent subjective scores, 100 and 99, respectively. ''Protect Non-resource Users From Physical Harm'' was ranked sixth and assigned a score of 35. Other goals were assigned scores of equal interval within the range of 65 - 95 as shown in Table 8.

Churchman-Ackoff Procedure Phase II

A total of 10 bundles comparisons were made as shown in Table 1. Responses of B, EQUAL, EQUAL, EQUAL, A, A, A, A, A, and A were made for comparisons 1 - 10, respectively. The 3 ''EQUAL'' responses to comparisons of Goal 1 (Assure

Table 7. Final list of major work activities of Virginia wildlife law enforcement agents.

Activity Number	Activity
1.	Inspect Cold-water Fishermen
2.	Inspect Warm-water Fishermen
3.	Inspect Boaters and Equipment
4.	Inspect Bear Hunters
5.	Inspect Turkey Hunters
6.	Inspect Deer Hunters
7.	Inspect Trappers
8.	Inspect Squirrel Hunters
9.	Inspect Dove Hunters
10.	Inspect Waterfowl Hunters
11.	Assist Stream Stocking
12.	Assist Game Census
13.	Investigate Damage Complaints
14.	Inspect Game Check Stations
15.	Teach Hunter Safety
16.	Teach Boat Safety
17.	Public Relations Speaking Engagements
18.	Inspect License Agents
19.	Inspect Boat Landings
20.	Investigate Boating Accidents
21.	Investigate Hunting Accidents
22.	Inspect Special Permits
23.	Perform Non-specific Patrol of Enforcement Area
24.	Control illegal captive game
25.	Distribute Farm Game Seed

Table 8. Results of Phase I and Phase III of the Churchman-Ackoff procedure.

Abbreviated Goal Statement	Assigned Score	Adjusted Score	Adjusted Score (0-100 Scale)
1. Assure Agency Income	100.0	48.9	100.0
2. Maintain Desired Level of Resource Use	99.0	25.7	52.5
3. Maintain Equal Distribution of Resource Use	95.0	12.8	26.2
4. Protect Public and Private Property	80.0	6.4	13.1
5. Protect Resource Users	65.0	4.0	8.2
6. Protect Non-resource Users	35.0	2.1	4.3

Agency Income) with 3 different bundles of lower ranked goals suggest that the respondent either had difficulty in maintaining in his mind the additiveness of ''units of achievement'' of goals, or his subjective evaluations of importance of one or more goals were not stable during the comparisons. It is impossible to tell which of the latter was operational during the comparisons.

<u>Churchman-Ackoff Procedure Phase III</u>

Adjustments in Phase I importance scores as indicated by Phase II comparisons are made under the assumptions that valuations of stimuli are stable between comparisons and that valuations are additive. Thus, an ''Equal'' response at comparison 2 (Table 1) would make it illogical to make further adjustments based on comparisons 3 and 4. Table 8, column 3, shows adjusted and standardized adjusted scores. Consistent with assumptions of the procedure, adjusted goal importance weights were produced which yielded $O_2 + O_3 + O_4 + O_5 = O_1$ (Comparison 2). Standardization of adjusted scores to a scale of 0 - 100 allows comparison to the Phase I original importance values. It is readily observed that the relative positions of goal importance were modified considerably as a result of the Phase II comparisons. The adjusted scores would be considered to approximate more accurately the true relative importance of goals since information is contained from both Phase I and Phase II of the procedure.

Subjective Effectiveness of Activities

Table 9 shows the subjective effectiveness of activities in achieving goals as perceived by Col. McLaughlin. This matrix was then multiplied as shown in Equation 5 by the goal importance vector (Q, Table 8, column 3) to produce the goal-weighted activity effectivenesses (Table 9). The latter computation was accomplished by the WILDSTRAT program.

Designation of Activity Occurrence

Activity occurrence as designated by Col. McLaughlin resulted in 11 activities shown to be performed during all planning periods. These were activities 2, 3, 15, 16, 17, 18, 19, 20, 22, 23, and 24 (Table 7). Six activities (4, 6, 8, 9, 11, and 14) were shown to be performed during only a single planning period. This period was the first quarter of January, except in the case of activity 15 which was designated as occurring in the second quarter of January. Other designations are not discussed herein because for the purpose of this study, the actual designations are not of as much interest as the fact that this phase of the WILDSTRAT SYSTEM was demonstrated as

Table 9. Subjective effectiveness of activities and goal-weighted effectiveness of activities (W_b).

Activities[2]	Goals[1] 1	2	3	4	5	6	(W_b)
1	9.5	8.5	8.5	4.0	0.5	0.2	820
2	9.5	8.5	8.5	2.0	0.2	0.0	806
3	9.0	0.0	0.0	9.0	9.5	0.0	534
4	8.5	9.0	9.0	2.0	1.0	1.0	781
5	8.5	9.0	9.0	0.0	0.0	0.0	763
6	9.0	9.0	9.0	8.0	2.0	5.0	857
7	8.0	7.5	0.5	4.0	0.0	2.0	620
8	9.0	8.5	8.5	6.0	1.0	0.5	811
9	9.0	8.5	8.5	3.0	0.5	0.0	789
10	9.0	7.5	8.0	0.5	0.5	0.0	741
11	9.5	10.0	8.5	0.0	0.0	0.0	831
12	0.0	1.0	1.0	0.0	0.0	0.0	39
13	0.0	0.0	0.0	9.5	0.0	0.0	61
14	0.0	1.0	1.0	0.0	0.0	0.0	39
15	1.0	7.0	4.0	6.0	9.5	9.5	375
16	0.0	0.0	0.0	9.0	9.0	0.0	92
17	5.0	5.0	5.0	4.0	4.0	5.0	489
18	8.5	0.0	0.0	0.0	0.0	0.0	416

Table 9. Continued.

	Goals[1]						
Activities[2]	1	2	3	4	5	6	(W_b)
19	1.0	9.0	0.0	7.5	0.0	0.0	328
20	0.0	0.0	0.0	9.0	9.0	0.0	92
21	0.0	0.0	0.0	9.0	9.5	9.0	113
22	7.0	0.5	0.0	0.0	0.0	0.0	355
23	9.5	9.5	9.5	9.0	6.0	6.0	924
24	0.0	3.0	3.0	0.0	0.0	0.0	116
25	2.0	3.0	3.0	0.0	0.0	0.0	213

[1] By order of presentation in Table 8.

[2] By order of presentation in Table 7.

feasible in an actual application.

As with other questionnaires administered in the case-study, no problems were reported by the respondent in interpreting directions or completing the computer-generated instruments.

Workload Index Data Collection

In order to facilitate alignment of workload indices with major work activities (Table 7), activities 2 and 3 each were split to ''Open Water'' and ''River'' categories which yielded 4 potentially distinct activities, ''Inspect Warm-water Fishermen, Open Water'', ''Inspect Warm-water Fishermen, River'', ''Inspect Boaters and Equipment, Open Water'', and ''Inspect Boaters and Equipment, River''. Also, activity 10 was split to ''River'' and ''Wetland'' categories, activity 12 to ''Deer'' and ''Bear'' categories, and activity 22 to ''Openland'', ''Forest'', and ''Open Water'' categories.

The main reason for making these partitions was to allow more refined computation of workload distribution. To combine measures of different units (such as acres of commercial forest and POWER system grid cells of open water) into a single index would require the assumption that a grid cell showing the presence of open water was of equal workload to an acre of commercial forest or a relative weighting of the two would be necessary. However, partitioning activities as described above avoids the problem of adjusting measures of different units to workload equivalence.

However, since subjective effectiveness of activities and designation of activity occurrence were only evaluated for the the original, more general activity list, the assumption was then required that effectiveness ratings and activity occurrence would be the same for partitioned subcategories as they were for the more general activity. This latter assumption was made only to facilitate demonstration of the WILDSTRAT SYSTEM. A re-administration of the Subjective Effectiveness of Activities and Designation of Activity Occurrence questionnaires would effectively eliminate the latter assumption.

Alignments shown in Table 10 reflect an interaction of factors such as data accuracy, availability, and closeness of fit to hypothesized ''true'' workload measures. Examination of these alignments can tell even the most casual of observers that great strides are needed in law enforcement workload estimation. It is suspected at this time that most wildlife law enforcement agencies do not even have the crudest of indices available in a form suitable for analysis. These data (Table 10) were available on a county basis from an independent source

Table 10. Alignment of workload index variables and major wildlife law enforcement work activities.

Activity	Workload Index Variable Assigned
Inspect cold-water fishermen	Miles of native and stockable troutwater
Inspect warm-water fishermen, open water	Power System grid cells, open water
Inspect warm-water fishermen, river	Power System grid cells, river
Inspect boaters and equipment, open water	Power System grid cells, open water
Inspect boaters and equipment, river	Power System grid cells, river
Inspect bear hunters	Average bear harvest, 1966-1977
Inspect turkey hunters	Average spring turkey harvest, 1967-1977
Inspect deer hunters	Average deer harvest, 1966-1977
Inspect trappers	Total county trapping license sales, 1976
Inspect squirrel hunters	Acres commercial oak forest, 1977
Inspect dove hunters	Acres of harvested cropland, 1969
Inspect waterfowl hunters, river	Power System grid cells, river
Inspect waterfowl hunters, wetlands	Power System grid cells, wetlands (Swamp, wooded, submerged)

Table 10. Continued.

Activity	Workload Index Variable Assigned
Assist stream stocking	Number of stocking trips, 1977-1978
Assist game census	Power System grid cells, state game areas
Investigate damage complaints, deer	Average deer harvest, 1966-1977
Investigate damage complaints, bear	Average bear harvest, 1966-1976
Inspect game check stations	Number of big game check stations, 1978-1979
Teach hunter safety	Total human population, 1975
Teach boat safety	Total boat registrations, 1976
Public relations speaking engagements	Total human population, 1975
Inspect license agents	Number of license agents, 1976
Inspect boat landings	Power System grid cells, total access points and boat ramps
Investigate boating accidents	Total boating accidents investigated, 1973-1977

Table 10. Continued.

Activity	Workload Index Variable Assigned
Investigate hunting accidents	Total hunting accidents investigated, 1961-1977
Inspect special permits	Total human population, 1975
Perform nonspecific patrol of enforcement area, openland	Acres of cropland, 1969
Perform nonspecific patrol of enforcement area, forest	Total commercial forest, 1977
Perform nonspecific patrol of enforcement area, open water	Power System grid cells, open water
Control illegal captive game	Total human population, 1975
Distribute farm game seed	Total farms, 1969

(Virginia Polytechnic Institute and State University, Department of Fisheries and Wildlife Sciences) and it was knowledge of the existence of this source that determined to a large extent the choice of Virginia as a site for the case-study.

Computation of Manpower Distributions

Following aggregation of the required inputs as described previously (Table 4), the WILDSTRAT program was executed. Table 11 shows means and standard errors of the proportion of workload in each of 14 patrol areas (counties) in the J.E.B. Stuart Enforcement Districted as computed over 48 planning periods. WILDSTRAT output also shows workload distributions and lists of activities to be performed for each planning period, as well as complete summaries of major inputs. WILDSTRAT program execution for the case-study described herein required approximately 30 seconds of CPU time on a WATFIV compiler.

LOWCOST Optimality

Tests of the LOWCOST algorithm were performed prior to actual application in the case study. These tests were designed to determine the impact on final solutions of starting value transfer costs. Since starting values of C_i, Equation 15, could have an infinite number of

Table 11. Means and standard errors of percent manpower to deploy to patrol areas of the J.E.B. Stuart Enforcement District, Virginia.

Patrol Area	Mean Percent Deployment[1]	S.E.
Amherst	4.6	0.1
Bedford	7.9	0.1
Botetourt	6.8	0.2
Campbell	7.3	0.0
Carroll	5.9	0.1
Craig	3.1	0.1
Floyd	4.2	0.1
Franklin	10.0	0.1
Halifax	12.8	0.1
Henry	5.9	0.1
Montgomery	5.6	0.1
Patrick	5.0	0.0
Pittsylvania	13.9	0.1
Roanoke	7.0	0.1

[1] Computed over 48 planning periods as prescribed by the WILDSTRAT SYSTEM.

values depending on initial estimates of manpower transfers (X'_i), it was desirable to test whether X'_i = MaxR yielded the least cost solution as opposed to $X'_i = R$, $R \neq$ MaxR.

Three different decision problems were tested. For each problem, all variable costs (Equation 16), initial and desired distributions, number of hours per work day, and total available agent-hours were maintained as constants over several runs. Each run varied by the value selected for R and the values tested ranged from above and below MaxR. For example, in Test 1 (Table 12), the initial distribution of a total of 200 agent-hours among 5 patrol areas was set at 20% each. A test problem was hypothesized that the temporary desired distribution for a single planning period might be 30%, 10%, 10%, 20%, and 30% among patrol areas 1-5, respectively. In this problem, MaxR would be 10% of the total agent-hours available. The computation of MaxR does not include the possibility of moving 40 agent-hours from patrol area 2 to patrol area 3 and then moving 20 agent-hours from patrol area 3 back to 2 in order to achieve 30% in area 3. This is reasonable since to select a value of MaxR otherwise would not minimize transfer costs.

Tables 12, 13, and 14 show that MaxR as defined herein produced an initial set of cost coefficients that yielded

Table 12. Optimality Test 1 of LOWCOST solution to minimization of manpower transfer costs.

Run[1]	R (Hours)	Minimum Transfer Cost (Dollars)[2]
1	2	124.41
2	4	124.41
3	6	124.41
4	8	122.31
5	10	122.31
6	12	122.31
7	14	122.31
8	16	122.31
9	18	122.31
10	20	122.31
11	22	122.31
12	24	122.31
13	26	122.31
14	28	122.31

[1] All variables except R constant between runs.
MaxR at Run 10.

[2] Initial Distribution: 0.2 0.2 0.2 0.2 0.2
Desired Distribution: 0.3 0.1 0.1 0.2 0.3

Table 13. Optimality Test 2 of LOWCOST solution to minimization of manpower transfer costs.

Run[1]	R (Hours)	Minimum Transfer Cost (Dollars)[2]
1	31	166.39
2	32	166.39
3	33	167.19
4	34	167.19
5	35	167.19
6	36	166.39
7	37	166.39
8	38	166.39
9	39	166.39
10	40	166.39
11	41	167.19
12	42	166.39
13	43	166.39
14	44	166.39

[1] All variables except R constant between runs. MaxR at Run 8.

[2] Initial Distribution: 0.20 0.20 0.20 0.20 0.20
Desired Distribution: 0.01 0.24 0.05 0.40 0.30

Table 14. Optimality Test 3 of LOWCOST solution to minimization of manpower transfer costs.

Run [1]	R (Hours)	Minimum Transfer Cost (Dollars) [2]
1	53	265.60
2	54	265.60
3	55	265.60
4	56	265.60
5	57	265.60
6	58	265.60
7	59	265.60
8	60	265.60
9	61	265.60
10	62	265.60
11	63	265.60
12	64	265.60
13	65	265.60
14	66	265.60

[1] All variables except R constant between runs. MaxR at Run 8.

[2] Initial Distribution: 0.1 0.4 0.2 0.2 0.1
Desired Distribution: 0.5 0.1 0.1 0.3 0.0

least cost solutions in each of 3 different problem formulations. Other values R $\neq$ MaxR also yielded minimized total costs of the same amount as MaxR in any one problem, but no other value of R $\neq$ MaxR produced a solution of lower total cost than MaxR. Therefore, it can be concluded that MaxR will set initial cost coefficients at values which most likely converge to produce a least cost global optimum. The costs of verifying this conclusion analytically at this time would exceed the benefits to be obtained by doing so, however. It is important to note that in each test, total costs as solved in different runs were relatively insensitive to changes in values of R, rarely varying more than an estimated 1% of the average total cost over all runs.

Manpower Transfer for J.E.B. Stuart Enforcement District

As will be recalled regarding assumptions of the LOWCOST algorithm, agents are assumed to have a permanent headquartered distribution about which they move in meeting workload demand. Since the workload distributions as computed by WILDSTRAT vary by planning period, these distributions are considered temporary and agents assumed to return to the permanent distribution no later than the end of each planning period.

Two approaches were employed in computing least cost strategies for achieving the temporary WILDSTRAT workload distributions. First, in a descriptive model, least cost manpower transfers were obtained assuming a permanent distribution of manpower as it actually existed in J.E.B. Stuart Enforcement District at the time of the study. Second, in simulation models, hypothesized permanent distributions were tested. In both approaches, the WILDSTRAT workload distributions over 48 planning periods (1 year) were used as temporary constraints (Equation 13) to be met in minimizing costs of manpower transfer. LOWCOST solutions for this many periods in a single run required approximately 45 minutes of CPU time.

Descriptive Model. Agents of rank Officer or Sergeant were assumed to provide 60 agent-hours of work per 6-day work week. Lieutenants were assumed to provide 30 agent-hours per man for major work activities and other effort expended in administrative duties. Therefore, a patrol area with one Officer and one Lieutenant would have a total of 90 agent-hours available for enforcement deployment. No agent-hours were assumed to be contributed by the Captain towards major work activities as it is conceivable that all available time of agents of this rank would be allocated to administration. The permanent distribution of agent-hours for J.E.B. Stuart Enforcement District (Table 15) was

Table 15. Permanent manpower distributions used in models of manpower transfer in J.E.B. Stuart Enforcement District, Virginia.

Patrol Area	Descriptive Model (Hours)	Simulation			
		I[a] (Hours)	II[b] (Hours)	III[c] (Hours)	IV[d] (Hours)
Amherst	90	57	60	90	90
Bedford	120	95	120	120	120
Botetourt	60	81	60	60	60
Campbell	120	87	120	120	120
Carroll	60	71	60	60	60
Craig	60	37	60	60	120
Floyd	60	50	60	60	60
Franklin	150	120	120	150	150
Halifax	120	153	150	180	120
Henry	60	71	60	60	60
Montgomery	60	67	60	60	60
Patrick	60	60	60	60	60
Pittsylvania	120	167	150	180	120
Roanoke	60	84	60	60	60
Total	1200	1200	1200	1320	1260

[a] Ideal Distribution

[b] Shift Existing Personnel

[c] Hire New Personnel and Locate Appropriately

[d] Hire New Personnel and Locate Inappropriately

computed according to information supplied by Capt. Eakin, Supervisor of the District, and these assumptions. Other assumptions for this model (and the simulations) were that the average salary per hour was $5.00, vehicle cost per mile $0.15, meals per day $7.50, lodging per night (if necessary) $16.00, and average vehicle speed in transit between patrol areas 45 mph.

Table 16 shows that with the present distribution, total costs over 1 year of 48 deployments would be $22,446. The transfer strategies prescribed would yield 98.3% of the total time available for work and only 1.7% would be lost to travel between patrol areas. A total of 548 shifts of manpower between patrol areas would be required over all planning periods.

Simulation Models. The permanent distribution employed in Simulation I (Table 15) represented an ''ideal'' optimal distribution set at the mean WILDSTRAT workload distribution (Table 11). Therefore movements of manpower between patrol areas would be expected to be minimized due to a closer fit (on the average) between the permanent and temporary WILDSTRAT prescribed distributions. Compared to the descriptive model, Table 16 shows that costs would be reduced nearly 43% (to $12,836) if the Simulation I permanent distribution could be achieved. However, since

Table 16. Cumulative results of transfer cost minimization in achieving WILDSTRAT prescriptions over 48 planning periods for 5 different permanent manpower distributions.

Permanent Distribution	Total Cost (Dollars)	Overall[1] Efficiency (Percent)	Total Transfers	Cost per Transfer (Dollars)
Descriptive Model	22,446	98.3	548	40.95
Simulation I	12,836	98.7	524	24.50
Simulation II	16,374	98.4	540	30.32
Simulation III	21,012	98.4	573	36.67
Simulation IV	27,278	98.1	583	46.79

[1] Overall Efficiency = (Total Agent Hours - Total Travel Time) / Total Agent Hours

shifts of existing agents would involve 60 or 30 agent-hour increments, it is unlikely that the Simulation I permanent distribution could be effected. Simulation II represents realistic shifts possible in the existing permanent distribution. This would be to move permanently a Lieutenant from Franklin patrol area to Halifax patrol area thereby yielding 120 and 150 agent-hours available in Franklin and Halifax areas, respectively. Also, a Lieutenant would be moved from Amherst to Pittsylvania. These personnel would be expected to move about the new location in order to meet work demand. As can be observed by comparing the descriptive model permanent distribution to the permanent distribution of Simulation I (Table 15), the existing manpower distribution in J.E.B. Stuart Enforcement District was a close fit to the mean WILDSTRAT distribution (Table 11). Therefore, the permanent re-locations of personnel in Simulation II represent minor adjustments in the existing distribution. Table 16 shows that these adjustments would reduce transfer costs below that of the present distribution approximately 27% to $16,374.

Simulation III represents the decision to hire new personnel instead of permanently re-locating presently employed agents. Since Halifax and Pittsylvania areas show the greatest demand, not only relative to other areas but also as compared to present staffing (Table 15), the hiring of new Officers for each was simulated. This increased the total agent-hours available from 120 to 180 in each of the latter areas. As a result, the total miminized costs of manpower transfer in the district would amount to $21,012 (Table 16). This suggests that addition of personnel to the existing system in the latter described fashion may actually imbalance the manpower/workload equilibrium thereby resulting in costs only slightly less than would movements of the existing distribution. This alternative would seem even more prohibitive in consideration of the fact that the latter figure does not include total salary of new agents but only that of paying them (and other agents) to move between areas. Consequently, the first three simulations suggest that relocation of existing personnel in the J.E.B. Stuart Enforcement District would reduce costs below that of the present distribution and be the most cost-effective means to achieve WILDSTRAT distributions. This finding for the district studied would not necessarily apply to other applications and it is quite likely that in other enforcement systems hiring of new personnel would be the most cost-effective method of achieving desired distributions. The WILDSTRAT SYSTEM provides the administrator with a method for making such determinations.

Simulation IV was performed in order to demonstrate the effect on total costs of manpower transfer of inappropriate location of new personnel. In this case, the addition of a new Officer in the Craig patrol area was simulated. Tables 11 and 15 show this area had the lowest relative workload and personnel would be expected to move out of it frequently to meet demand elsewhere. By adding an agent in this area, the permanent manpower distribution was placed at a significant disparity from the mean prescribed distribution. Table 16 shows this effect translated into total costs of $27,278 which represent an increase of 22% that of the existing distribution or 66% more than that of re-locating existing personnel (Simulation II).

Table 16 also shows, in general, that efficiency ((Total agent-hours available - Total travel time) / Total agent-hours available) varied only slightly with changes in permanent manpower distributions. This shows that as costs decreased by improving the fit between permanent and temporary distributions (thereby reducing the number of overnight deployments) a relative increase in the number of commuting deployments dampened the overall rate of change in efficiency.

During solution of simulation problems, it was found on occasion that convergence to an optimal solution would not occur for certain problem formulations. As a result, the LOWCOST program was modified to allow convergence to approximate solutions. This was accomplished by setting all transfer coefficients (a_{ki}, Equation 13) equal to 1.0, which produced solutions accurate to ± 1.0% of all desired deployment constraints. Assuming all a_{ki} as constants is a frequently employed method of solving transportation problems, since by doing so, problem solutions are readily obtained at reasonable accuracy. Also, cost coefficients (C_i) reflect essentially the same economies of scale as the transfer coefficients.

Table 17 shows partial output of the LOWCOST program, demonstrating the versatility of the program, not only as a tool for comparing the effect on cost of different permanent manpower distributions, but also as an administrative aid in directing field operations. Assuming a goal-oriented management system, administrators can use WILDSTRAT SYSTEM outputs as guidelines for directing regional deployment of field personnel.

Research Goal II

The Dependent Variable

Table 18 shows results of Phase I of the violation seriousness scaling, i.e. the development of importance values of goals according to Thurstone's (1927) PC

Table 17. Partial output from LOWCOST showing least cost manpower transfer necessary to achieve the WILDSTRAT deployment during a single planning period.

INTERPRETING LOWCOST OUTPUT

THE USE OF ''LOWCOST'', AS FOR ''WILDSTRAT'', REQUIRES SOME ADMINISTRATIVE JUDGMENT. THIS JUDGMENT SHOULD BE APPLIED IN THE CONTEXT THAT LOWCOST PROVIDES GUIDELINES FOR ACTION RATHER THAN RULES TO FOLLOW. REFERENCE TO THE QUESTIONNAIRE WHICH WAS PROVIDED PRIOR TO USE OF LOWCOST WILL ALLOW A REVIEW OF MAJOR ASSUMPTIONS OF THE METHOD AND ILLUSTRATE WHY IT SHOULD BE TREATED AS SUGGESTED ABOVE. LOWCOST OUTPUT CONSISTS OF A SERIES OF SOLUTIONS TO MANPOWER RE-DISTRIBUTION PROBLEMS, ONE 3 PAGE SECTION PER PLANNING PERIOD. THE LAST TWO PAGES OF OUTPUT FOR ANY RUN PROVIDE A SUMMARY OF THE ENTIRE RUN AND ARE PARTICULARLY IMPORTANT WHEN USING LOWCOST AS A SIMULATOR.

EACH 3-PAGE SECTION (ONE PER PLANNING PERIOD) IS HEADED BY A TITLE:

LOWCOST
FOR
PLANNING PERIOD (NUMBER)

THIS PAGE IDENTIFIES THE PLANNING PERIOD UNDER CONSIDERATION IN THE NEXT 2 PAGES AND PROVIDES A SUMMARY OF THE MAJOR INPUTS DESCRIBING THE MANPOWER DISTRIBUTION PROBLEM FOR THAT PLANNING PERIOD. THIS PAGE ALSO SERVES THE USER AS A LISTING OF THE MAJOR VARIABLES WHICH CAN BE ADJUSTED OR CHANGED TO PROVIDE ANSWERS TO THE GENERAL QUESTION ''WHAT IF . . . ?''. THUS LOWCOST CAN BE USED TO DESCRIBE CLOSELY AN EXISTING SITUATION OR TO SIMULATE HYPOTHETICAL AND PLANNED SITUATIONS.

THE SECOND PAGE OF EACH PROBLEM SOLUTION DESCRIBES MOVEMENTS WHICH WOULD HAVE TO BE MADE BY PERSONNEL IN ORDER TO ACHIEVE THE WILDSTRAT OPTIMAL DISTRIBUTION FOR THAT PLANNING PERIOD. THE FIRST COLUMN CONSISTS OF A LIST OF STATEMENTS ''FROM (NO.) TO (NO.)'' PROVIDING THE CODE NUMBERS FOR THE ''SOURCE'' PATROL AREA WHICH MUST DELIVER SOME AMOUNT OF AGENT-HOURS TO A ''DESTINATION'' PATROL AREA. THE SECOND COLUMN INDICATES THE NUMBER OF AGENT-HOURS TO DEPLOY, INCLUDING TRAVEL TIME. THE THIRD COLUMN LISTS THE STRAIGHT-LINE DISTANCE BETWEEN THE TWO POINTS COMPUTED BY THE PROGRAM. THE FOURTH COLUMN LISTS THE EFFICIENCIES OF THE MOVEMENTS, INDICATING THE PROPORTION OF THE TOTAL HOURS DEPLOYED WHICH WILL BE AVAILABLE FOR PATROL IN THE DESTINATION PATROL AREA. THIS WILL ALWAYS BE LESS THAN 100% (1.00) BECAUSE A PORTION OF THE TIME DEPLOYED IS SPENT IN TRANSIT TO AND FROM THE DESTINATION COUNTY. THE FIFTH COLUMN INDICATES THE LOWEST COST METHOD OF PROVIDING AGENT-HOURS TO THE DESTINATION PATROL AREA, EITHER OVERNIGHT (O) OR COMMUTE (C). AN OVERNIGHT MOVEMENT ASSUMES ONLY ONE TRIP PER UNIT WILL BE MADE TO THE DESTINATION PATROL AREA AND THAT UNIT WILL REMAIN OVERNIGHT AS MANY NIGHTS AS IS NECESSARY TO EXPEND THE TOTAL AGENT-HOURS DEPLOYED. IF DEMAND IN A DESTINATION PATROL AREA IS HIGH, MORE THAN ONE UNIT MAY BE REQUIRED TO BE DEPLOYED IN ORDER TO PROVIDE THE TOTAL AGENT-HOURS NEEDED DURING THE PLANNING PERIOD. IF THIS WOULD BE THE CASE, THE ENTRY IN THE SIXTH COLUMN WILL INDICATE THIS. THE NUMBER OF ROUND TRIPS NEEDED PER VEHICLE IS COMPUTED UNDER THE ASSUMPTION THAT ONLY ONE AGENT WILL BE DEPLOYED PER VEHICLE. THUS, FOR ANY OVERNIGHT DEPLOYMENT, IF THE NUMBER OF VEHICLE ROUND TRIPS (COL. 6) IS GREATER

Table 17. Continued.

THAN 1, MORE THAN ONE UNIT MUST BE DEPLOYED OVERNIGHT TO THE DESTINATION PATROL AREA FROM THE SPECIFIED SOURCE PATROL AREA. FOR A COMMUTER MOVEMENT, COSTS ARE COMPUTED UNDER THE ASSUMPTION THAT THE UNIT DEPLOYED WILL RETURN TO THE SOURCE PATROL AREA AT THE END OF EACH FULL WORK DAY. IF THE NUMBER OF VEHICLE ROUND TRIPS NECESSARY (COL. 6) IS GREATER THAN THE NUMBER OF DAYS PER PLANNING PERIOD, THEN ON AT LEAST ONE DAY MORE THAN ONE UNIT WILL HAVE TO BE DEPLOYED FROM THE SOURCE PATROL AREA TO THE DESTINATION PATROL AREA. COLUMN 7 PROVIDES THE COSTS OF MAKING THE MOVEMENTS PRESCRIBED. COSTS DO NOT INCLUDE COST OF PATROL IN THE DESTINATION PATROL AREA, ONLY THE COSTS OF GETTING A UNIT THERE.

SINCE THE LOWCOST PROGRAM IS DESIGNED TO PROVIDE SOLUTIONS WHICH WILL NOT ALLOW SLACK TIME IN ANY PATROL AREA, MOVEMENTS OF VERY LOW EFFICIENCY FOR SHORT AGENT-HOUR ALLOCATIONS MAY BE PRESCRIBED. IN SUCH CASES, THE ADMINISTRATOR SHOULD FOCUS HIS ATTENTION ON THOSE MOVEMENTS WHICH INVOLVE LARGER AGENT-HOUR DEPLOYMENTS AT HIGHER EFFICIENCIES. TO INSTRUCT AN AGENT TO SPEND EVEN A SMALL PORTION OF HIS TIME MERELY DRIVING TO A DESTINATION AREA AND BACK WOULD DEFEAT THE PURPOSES OF IMPROVED ADMINISTRATION. THUS, PRACTICAL USE OF LOWCOST GUIDELINES MIGHT REQUIRE A DECISION TO MOVE MANPOWER ONLY IF SOME MINIMUM NUMBER OF EFFECTIVE AGENT-HOURS WOULD BE DELIVERED TO THE DESTINATION PATROL AREA.

THE THIRD PAGE SHOWS THE RESULTANT YIELD OF EFFECTIVE PATROL HOURS IN EACH PATROL AREA AFTER DEPLOYMENT ACCORDING TO THE LOWCOST SOLUTION. IT ALSO SHOWS THE COST PER PATROL AREA TO MAKE SUCH DEPLOYMENT. PLEASE NOTE THAT THE PERCENT EFFECTIVE HOURS PER PATROL AREA WILL EQUAL OR BE VERY CLOSE TO THE PRESCRIBED WILDSTRAT DISTRIBUTION. THUS IT IS APPARENT THAT THE LOWCOST SYSTEM BALANCES EFFECTIVE PATROL HOURS AMONG THE PATROL AREAS. ALTHOUGH THERE MAY BE MANY SOLUTIONS TO ACHIEVING THE WILDSTRAT DISTRIBUTION, LOWCOST PROVIDES THE LEAST COST, MOST EFFECTIVE SOLUTION. FREQUENTLY THE COST OF ACHIEVING SOME NUMBER OF AGENT-HOURS FOR A PARTICULAR PATROL AREA WILL BE SHOWN AS EQUAL TO ZERO. IN SUCH AN AREA, THE AGENT-HOURS DEPLOYED ARE ACHIEVED BY THE AGENT STAYING IN HIS OWN AREA AND NOT MOVING OUT FOR AT LEAST AS MANY HOURS AS SHOWN. THE ADMINISTRATOR SHOULD NOT INTERPRET TRANSFER COSTS AS ADDITIONAL COSTS. IN MANY CASES THE COSTS ARE ALREADY BEING INCURRED BY ON-GOING PATROL.

AT THE END OF EACH RUN OF THE LOWCOST PROGRAM, A JOB SUMMARY IS PROVIDED. COMPARISON BETWEEN RUNS OF GRAND TOTALS FOR COSTS AND YIELD OF EFFECTIVE HOURS ALLOWS ANALYSIS OF THE EFFECTS OF MODIFICATIONS IN PERMANENT DISTRIBUTIONS AND/OR COST FACTORS. THE JOB SUMMARY ALSO SHOWS HOW MANY MOVEMENTS MUST BE MADE PER PLANNING PERIOD AND AN INDEX OF THE COMPUTER TIME REQUIRED TO PROVIDE EACH SOLUTION. THE LARGER THE EXECUTION INDEX, THE MORE TIME WAS REQUIRED.

Table 17. Continued

LOWCOST

FOR

PLANNING PERIOD 1

J. E. B. STUART ENFORCEMENT DISTRICT

PATROL AREA CODE	PATROL AREA	INITIAL DISTRIBUTION (PERCENT TOTAL MANPOWER)	WILDSTRAT DISTRIBUTION (PERCENT TOTAL MANPOWER)
1	AMHERST	7.50	4.60
2	BEDFORD	10.00	9.40
3	BOTETOURT	5.00	10.80
4	CAMPBELL	10.00	6.70
5	CARROLL	5.00	6.00
6	CRAIG	5.00	5.70
7	FLOYD	5.00	4.00
8	FRANKLIN	12.50	8.60
9	HALIFAX	10.00	12.30
10	HENRY	5.00	4.60
11	MONTGOMERY	5.00	5.10
12	PATRICK	5.00	5.10
13	PITTSYLVANIA	10.00	11.90
14	ROANOKE	5.00	5.20

TOTAL AGENT-HOURS AVAILABLE 1200.0

THE FOLLOWING DATA ARE USED TO COMPUTE MANPOWER MOVEMENTS WHICH WILL ACHIEVE THE WILDSTRAT DISTRIBUTION MOST EFFECTIVELY AND AT LEAST COST. PLEASE CHECK FOR ACCURACY.

NO. OF WORKDAYS IN PLANNING PERIOD	6.00
AVERAGE HOURS PER WORK DAY	10.00
AVERAGE SALARY PER HOUR	5.00
AVERAGE VEHICLE SPEED	45.00
VEHICLE COST PER MILE	0.15
COST OF LODGING PER NIGHT	16.00
COST OF MEALS PER DAY	7.50

THE APPROXIMATE SOLUTION MODE WAS USED FOR THIS RUN

Table 17. Continued

MANPOWER TRANSFER	TOTAL HOURS TRANSFERRED (THT)	MILES DISTANCE	EFFICIENCY (THT-TRAVEL TIME/THT)	METHOD[A]	NO. VEHICLE ROUND TRIPS NECESSARY[B]	TRANSFER COST (DOLLARS)[C]
FROM 10 TO 12	1.2	22.0	0.187	C	1	12.37
FROM 4 TO 3	27.6	22.4	0.892	C	3	55.75
FROM 8 TO 9	27.6	56.3	0.999	O	1	82.12
FROM 1 TO 3	34.8	31.5	0.960	O	1	90.52
FROM 2 TO 3	7.2	20.2	0.875	C	1	15.96
FROM 10 TO 13	3.6	27.8	0.656	C	1	17.24
FROM 9 TO 13	19.2	30.0	0.861	C	2	45.75
FROM 4 TO 14	2.4	16.5	0.695	C	1	10.40
FROM 4 TO 11	1.2	34.4	0.0	C	1	18.84
FROM 7 TO 5	12.0	25.7	0.809	C	2	35.87
FROM 4 TO 6	8.4	20.6	0.849	C	1	21.22

****

A
C=COMMUTER
O=OVERNIGHT

B
C -AGENT WILL RETURN TO HOME PATROL AREA AFTER EACH WORKDAY OF 10.0 HOURS.
O -TOTAL HOURS DEPLOYED SPLIT AMONG AS MANY AGENTS AS ROUND TRIPS. RETURN TO HOME PATROL AREA AT WORK COMPLETION

C
FOR ALL TRANSFERS, LEAST COST METHOD IS METHOD SHOWN.

Table 17. Continued

ESTIMATED TOTAL EFFECTIVE PATROL HOURS PER PATROL AREA

	PATROL AREA	TOTAL EFFECTIVE PATROL HOURS	PERCENT	COST
1	AMHERST	55.20	4.67	0.0
2	BEDFORD	112.80	9.54	0.0
3	BOTETOURT	124.32	10.52	162.24
4	CAMPBELL	80.40	6.80	0.0
5	CARROLL	69.71	5.90	35.87
6	CRAIG	67.13	5.68	21.22
7	FLOYD	48.00	4.06	0.0
8	FRANKLIN	103.20	8.73	0.0
9	HALIFAX	145.10	12.28	82.12
10	HENRY	55.20	4.67	0.0
11	MONTGOMERY	60.00	5.08	18.84
12	PATRICK	60.22	5.10	12.37
13	PITTSYLVANIA	138.89	11.75	62.99
14	ROANOKE	61.67	5.22	10.40
	TOTAL	1181.84		406.05

98.5 % OF THE TOTAL HOURS AVAILABLE WILL BE EFFECTIVE PATROL HOURS

1.5 % OF THE TOTAL HOURS AVAILABLE WILL BE SPENT IN TRANSIT

JOB SUMMARY

PLANNING PERIOD	TOTAL TRANSFER COST	TOTAL EFFECTIVE HOURS	TOTAL TRANSFERS	EXECUTION INDEX
1	406.05	1181.8	11	20
2	499.44	1176.2	11	19
TOTALS:	905.49	2358.0	22	39

Table 18. Proportion of times a column goal was judged more important than a row goal and final scale values of goal importance.

Goals[1]	2	6	4	1	5	3
2	0.500	0.534	0.500	0.669	0.632	0.724
6	0.466	0.500	0.555	0.585	0.610	0.635
4	0.500	0.445	0.500	0.500	0.600	0.619
1	0.331	0.415	0.500	0.500	0.538	0.644
5	0.368	0.390	0.400	0.462	0.500	0.559
3	0.276	0.365	0.381	0.356	0.441	0.500
Sum p_{ij}[2]	2.441	2.649	2.836	3.072	3.321	3.681
Final scale values	1.000	1.093	1.172	1.273	1.378	1.535

[1] Refers to Phase I goals identified in the methods section.

[2] Summation of the proportion of times column goal i was selected over row goal j.

procedure. Tests of internal consistency (Beattie et al. 1978) showed that respondents were very consistent in making PC judgments, partially verifying the assumptions of the Case V model. Thus, the scale values could be considered accurate approximations of the relative importance of goals as perceived by the surveyed population of enforcement personnel. Since goal importance could only be determined for the 5 goals shown in Table 18, it was necessary to assign an importance value to the seventh, non-specific goal defined as ''Combined Division or Other Goals''. The median (1.222) of the 5 scale values shown in Table 18 was assigned as the value of this latter goal. Table 19 shows the mean seriousness of negative impact on achievement of goals and goal-association of each of the Phase II stimuli. Goal-weighted violation seriousness of each of these stimuli were computed as described previously and shown in Table 19. Table 20 shows the QAS determined for each type of arrest found in the raw arrest data. The Quality Arrest Scores shown in Table 20 were computed as described in METHODS based on the goal-weighted violation seriousness values shown in Table 19.

Totals of 1498, 163, 1445, and 802 arrests were processed for the months of November, February, May and August, respectively. Observations of arrest productivity were provided voluntarily by 110, 117, 112, and 117 (total

Table 19. Wildlife law violation seriousness as perceived by Virginia wildlife law enforcement personnel.

Law	Associated Goal	Mean Seriousness of Negative Impact	Goal-weighted Violation Seriousness
Hunt migratory birds closed season	1	9.196	11.707
Hunt deer and bear with dogs	1	7.589	9.661
Fish during closed season	1	8.140	10.362
Hunt migratory birds after hours	1	8.664	11.029
Trap furbearers during closed season	1	8.860	11.279
Setting traps on beaver dam	1	7.178	9.138
Hunting during closed season	1	9.792	12.465
Hunting quail on snow	1	5.566	7.086
Possession of game fish during closed sea.	1	7.877	10.027
Snagging or gigging certain species	1	7.290	9.280
Hunting game during unlawful hours	1	9.094	11.577
Take fish with certain bait, nets, devices	1	8.047	10.244
Exceed size limit of game fish	1	6.240	7.944
Kill game of a certain sex	1	8.800	11.202
Hunt migratory birds over bait	2	9.352	9.352
Exceed creel limit of game fish	2	8.813	8.813
Exceed bag limit of game	2	9.617	9.617
Destroy identity of game prior to checking	2	8.336	8.336
Hunting with unplugged guns, other dev.	2	7.935	7.935
Failure to tag big game at place of kill	2	7.514	7.514
Exceed bag limit of migratory birds	2	9.206	9.206

Table 19. Continued.

Law	Associated Goal	Mean Seriousness of Negative Impact	Goal-weighted Violation Seriousness
Illegal to detach a game tag	2	7.112	7.112
Immediately take big game to check station	2	7.417	7.417
Trespass while trapping furbearers	3	8.057	12.367
Deposit litter or trash	3	9.346	14.346
Trespass while fishing	3	7.738	11.325
Trespass while hunt. migratory birds	3	8.047	12.352
Hunt private land without permission	3	8.822	13.542
No throwable device on boat	4	6.538	7.663
Careless and reckless boat operation	4	9.972	11.687
Tow skier at certain times of day	4	8.393	9.837
Unservice. life preserver on boat	4	8.729	10.230
Boat lacking proper venting	4	8.570	10.044
Operate boat at night, no lights	4	9.467	11.095
Operate boat without fire exting.	4	8.290	9.717
Violate uniform markers, boating	4	7.396	8.668
No spark arrestor, cert. boats	4	7.393	8.665
Operate boat while intoxica.	4	9.887	11.588
Oper. boat without certain saf. equip.	4	9.364	10.975
Certain boats no life preservers	4	9.150	10.724
Tow water skier without observer	4	6.962	8.159
Borrow or loan fish. license	6	9.365	10.236
Hunt game without forest stamp	6	7.047	7.702
Hunt mig. waterfowl, no duck stamp	6	7.589	8.295
Hunt mig. birds unlicensed blind	6	6.888	7.529

Table 19. Continued.

Law	Associated Goal	Mean Seriousness of Negative Impact	Goal-weighted Violation Seriousness
Operate boats without certificate	6	6.748	7.376
Use dipnet without license	6	7.505	8.203
Purchase improper hunting lic.	6	10.075	11.012
False statement apply. hunt lic.	6	10.458	11.431
Hunt b. game without b. game license	6	10.196	11.144
False statement apply. fish. lic.	6	10.355	11.318
Hunt without license	6	10.009	10.940
Operate boat with expired certificate	6	8.495	9.285
Fish certain streams without trout lic.	6	8.439	9.224
Trap furbearers without valid lic.	6	9.336	10.204
Fish without forest stamp	6	6.860	7.498
Hunt game without damage stamp	6	5.047	5.516
Fish without valid license	6	9.888	10.808
Hunt migratory birds without valid lic.	6	9.701	10.603
Improperly register boat	6	7.047	7.702
Borrow or loan hunting license	6	9.561	10.450
Fish with improper license	6	9.075	9.919
Buy fur without permit	6	8.486	9.275
Failure to display boat number	6	7.243	9.917
Hunt mig. birds with unplugged shotgun	7	7.202	8.801
Loaded pistol in boat	7	5.152	6.736
Hunt on Sundays	7	6.904	8.437
Not in court for boat violation	7	7.308	8.930
Fishing on Sunday in certain counties	7	2.581	3.154

Table 19. Continued.

Law	Associated Goal	Mean Seriousness of Negative Impact	Goal-weighted Violation Seriousness
Fishing after legal hours	7	5.093	6.224
Captive game without permit	7	7.262	8.874
Trespassing while boating	7	5.178	6.328
Locate blind within 500 yards of another	7	5.748	7.024
Fishing with unsigned license	7	2.832	3.461
Hunting from automobile	7	8.841	10.804
Import or transport certain species	7	8.519	10.410
Possession of game in closed season	7	8.906	10.883
Contribute to the delinquency of minor	7	8.140	9.947
Violate military hunting rules	7	6.542	7.994
No name on traps	7	7.007	8.565
Shoot waterfowl with running motor	7	7.991	9.765
Violate boat parking regulations	7	4.364	5.333
Hunt or shoot from highways	7	8.421	10.290
Uncased gun on Natl. For. at certain times	7	6.708	8.197
Sale and purchase of game animals	7	9.037	11.043
Muffle noise of motor boat	7	5.726	6.997
Not in court for fishing violation	7	7.467	9.125
Spotlighting game during certain hours	7	9.657	11.801
Resisting game warden	7	9.849	12.035
If convicted 2nd time, bond or jail	7	7.271	8.885
Must visit traps daily	7	8.028	9.810
Speed no wake zone	7	7.607	9.296
Fail to appear in court when summoned	7	8.084	9.879

Table 20. Quality arrest score assignment for all types of arrests made by Virginia wildlife law enforcement agents November 1977, February, May, and August 1978.

Virginia Code	QAS Assignment	Virginia Code	QAS Assignment
18.2-388	0.000	R-29-1	7.702
175.15A	0.000	29-140	7.935
46.1-350	0.000	R-16-2	7.935
18.2-250	0.000	R6-3.1A	7.935
18.2-87.1	0.000	R-20-2	7.935
29-34.1	0.000	R-20-1	7.935
13-9.1	0.000	L4-4	7.935
46.1-192	0.000	29-144.6	7.935
29-125	0.000	R-20-3	7.935
18.2-311	0.000	18.2-287A	7.935
29-144.3	0.000	R-23-3	7.944
14-4.1	0.000	R-2.5A	8.197
18.2-139	0.000	R2-5A	8.197
33-175.15	0.000	R2-5	8.197
18-31	0.000	29-110	8.203
33.1-350	0.000	R-25-4B	8.203
25.25-10	0.000	62.1-170	8.331
L3-1	5.516	62.1-170A	8.331
18.2-416	6.721	R6-9-D	8.336
29-143A	6.736	29-129	8.442
R-20-4	6.736	R-24-8	8.466
18.2-287	6.736	29-143H	8.565
62.1-175	6.997	R-28-5	8.668
R1-10	7.001	62.1-171	8.668
29-90	7.024	R-23-9	8.717
R6-9-A	7.112	R-24-4	8.813
R-29-5	7.376	62.1-1	8.827
R6-9-C	7.417	R-22-6	8.874
R6-9-B	7.514	29-103	8.874
R18-6B	7.514	29-77	8.885
29-156A	7.514	62.1-182	8.969
29-157	7.514	R-24-10.2	9.000
R-18-6B	7.514	R-24-10.1	9.000
R6-9	7.595	R4-2	9.138
R-18-6	7.595	29-163B	9.215
29-117	7.702	29-163C	9.215

Table 20. Continued.

Virginia Code	QAS Assignment	Virginia Code	QAS Assignment
29-55B	9.224	R-24-1	10.362
R-25-4A	9.224	R-24-2B	10.362
R-23-11A	9.224	R3-4	10.409
29-93	9.275	10-68	10.590
R-26-1	9.280	62.1-172F	10.613
R-30-8	9.296	29-51	10.651
29-143D	9.352	29-75	10.651
29-143	9.418	29-79	10.651
R-25-4	9.473	R-28-1.1	10.724
R2-11	9.474	29-143F	10.804
R-19-2	9.545	29-76	10.889
R-29-7	9.601	29-58	10.910
29-143C	9.617	62.1-172D	10.975
R6-5	9.617	R-28-1	10.975
R6-6.1	9.617	29-143K	11.043
R6-11-B	9.661	29-164	11.043
29-173	9.703	29-162	11.095
62.1-172G	9.717	62.1-172B	11.095
29-143J	9.810	62.1-172C	11.095
62.1-169	9.917	R-28-2	11.095
R-29-4	9.917	29-59	11.142
62.1-169A	9.917	29-122	11.144
18.2-371	9.947	18.2-308	11.188
29-55	10.016	18.2-286	11.188
62.1-172	10.027	29-144	11.202
62.1-172K	10.027	R8-8	11.279
R-24-11	10.136	29-146	11.279
R6-3.1	10.200	29-57	11.318
29-148	10.201	29-63	11.318
29-161	10.228	29-163A	11.413
R-24-6	10.244	29-142.2	11.577
R-24-9	10.244	29-141	11.577
R-24-6A	10.244	29-134	11.583
29-153	10.244	18.2-285	11.588
R-25-6	10.244	62.1-176	11.588
29-144.5	10.290	46.1-189	11.687
29-163	10.314	18.2-56.1	11.687
29-129.1	10.314	29-143I	11.687
R-24-7	10.362	62.1-176A	11.687
R-24-2	10.362	62.1-177	11.687

Table 20. Continued.

Virginia Code	QAS Assignment	Virginia Code	QAS Assignment
29-144.4	11.801	18.2-133	12.397
29-144.4B	11.801	18.2-119	12.397
29-144.4A	11.801	18.1-173	12.397
29-144.2	11.948	18.1-134	12.397
29-147.1	12.021	R-17-6	12.465
18.2-464	12.035	29-163.2	12.465
29-32.2	12.035	33.1-346	14.346
18.2-132	12.397	62.1-194	14.346
18.2-134	12.397	18.2-324	14.346
29-165	12.397	10-209	14.346
29-166	12.397	33.1-346A	14.346
18.2-136	12.397	62.1-194A	14.346
29-168	12.397	10-197	14.346

= 456) respondents for the respective periods yielding response rates of 76%, 81%, 78%, and 76%.

As stated previously, the primary purpose for developing the QAS for each type of arrest was to increase the information content of the dependent variable over that which would be provided by numbers of arrests alone. A simple correlation of total QAS with total arrests (n=456) yielded a correlation coefficient of 0.9958 which was significant at P<0.0001. Therefore, numbers of arrests would explain 99.05% of the variance in total QAS in the present data. This high correlation suggests that agents make apprehensions in a relatively constrained range of the possible QAS scores shown in Table 20 and, thus, there is a very close correspondence between total QAS and numbers of arrests. Although it might be tempting to suggest substitution of raw arrest data for QAS measures in this analysis or future analyses, the close correlation observed herein does not suggest that the theoretical value of QAS measures of enforcement productivity is substitutable. Also QAS measures are superior to numbers of arrests for parametric statistical tests because the former represent measurement on a continuous scale whereas the latter are, technically, a discrete distribution.

The Kolmogorov-Smirnoff Goodness of Fit test of the null hypothesis that the distribution of dependent observations was normal was rejected at $P<0.001$. This rejection was most likely a result of the relatively large number of low values accompanied by several outliers of high magnitude thereby imparting a positive skew to the distribution. Frequency plots verified a positive skew and also indicated that a unimodal distribution existed. The skewness of the data could have bearing on later F tests. However it has been shown that F tests are robust and have acceptable properties even if the distribution is skewed. According to Scheffe (1959:346), ''From many sampling experiments with nonnormal distributions, it has been concluded that tests based on t for inferences about the mean of a single population, which are equivalent to F tests with 1 d.f. in the numerator, are <u>not</u> sensitive to skewness'' (Emphasis added). It should be recalled that the primary goal of this research was to evaluate the <u>relative</u> importance of factors affecting agent productivity and to identify the strongest relationships among a large array of independent variables rather than to test specific hypotheses. Therefore comparison of standardized regression coefficients or partial mean squares can provide the necessary insights without heavy reliance on normal theory.

The Independent Variables

Personal Background Characteristics. Applications for employment were released by 104 (72%) of the 144 Virginia law enforcement agents. Because this represented a high response rate, no attempt was made to obtain personal background data from non-respondents by other means. A major reason for using employment applications was to avoid bias due to professional experience as wildlife agents (such as could be incurred by concurrent flexibility indices), to avoid bias due to recall errors which may have been incurred by other evaluative tools (particularly regarding prior work experience and education), and to avoid further demands on the agents' time. Although scores from personality tests, background investigations, or personnel evaluations would have been useful as additional personal background variables, none were known to be consistently applied or available for all Virginia agents.

Missing data were encountered on a total of 67 of the applications, primarily restricted to the variables LOFLEX, JOFLEX, TRAFLEX, FISH and HUNT (See METHODS, Research Goal II, page 105, for descriptions). AGEAPP, MOSERV, and RANK were known for all personnel regardless of whether applications were obtained. Important variables related to work experience, health, military experience, and education were obtained from all 104 applications.

Because it was necessary to match personal background measures to each observation of arrest productivity, those agents who responded to arrest data collection but did not release personal background data were eliminated from certain analyses. Thus, although agent cooperation with efforts to obtain personal background data was good, the occurrence of non-respondents to requests for release of employment applications in the overall sample of arrest productivity reduced sample sizes in various statistical analyses.

Environmental Attributes. In order to justify combination of May and August data into a single data set to be used to develop the regression models of the form shown in Equation 26, univariate tests of hypotheses that no differences existed between study periods were made for each of the environmental attributes. One-way analysis of variance was used to perform these tests. No significant ($P<0.15$) differences due to study period were detected for any environmental attribute in these tests. Thus, the patrol area data for May and August were combined into a single data set and used to develop the regression equations. Table 21 lists environmental attributes and multiple correlation coefficients for the regression models

Table 21. Multiple correlation coefficients of regression models for prediction of patrol area charactistics from arrest area characteristics in May and August, 1978. No. observations = 183.

Variable[a]	R^2	Variable[a]	R^2
TOTRP	0.76	ACCPL	0.65
HUACCI	0.63	ACHVCPL	0.84
TOTAC	0.51	COMMERF	0.53
ACTRTWA	0.81	OAK	0.57
AVSPTK	0.67	TRTSTK77	0.85
AVFATK	0.90	STKTRP77	0.86
AVBRHV	0.86	TOWAREC	0.51
AVDEHV	0.74	GMNGT	0.65
TOTHU	0.52	TOREFU	0.20
TOTFA	0.84	TOTOTHHR	0.52

[a] See Methods for descriptions, page 112.

produced. In general, multiple correlation coefficients were high, 7 (ACTRTWA, AVFATK, AVBRHV, TOTFA, ACHVCPL, TRTSTK77, STKTRP77 - see page 112 for descriptions) of the 20 correlations exceeded 0.80 and all but one were greater than 0.50. Thus, predictions of patrol area characteristics in November and February were made for all environmental attributes except TOREFU and TOTOTHHR.

The predictions described above had the primary purpose of allowing study of the effects of patrol area characteristics on enforcement productivity over <u>all</u> study periods, i.e. to increase the sample size of observations with ''known'' patrol area characteristics. However, use of regression for predicting independent measures to be used in subsequent regression models may violate the statistical assumption that independent variables have been measured with neglible error. However, as evidenced by the multiple correlation coefficients (Table 21), error imposed on November and February independent measures by the predictive models was relatively slight and of little more concern than potential measurement error on other independent variables.

<u>Methods of Enforcement</u>. In space provided at the end of each Summons Data Sheet, agents were asked to describe ''Other'' methods used, if any. Of those described, no

consistent recurrence was detected. Mean percent (±S.E.) of total QAS made by ''Other'' methods was only 2.8±0.8, indicating that the contribution of ''Other'' methods to total productivity was relatively slight. Mean percent of total QAS (±S.E.) was 68.3±1.9, 10.6±1.1, 5.6±1.0, and 12.4±1.4 for Patrol, Stakeout, Investigation, and Citizen Notification methods, respectively (n=343).

In addition to evaluating models with Methods variables in the form of <u>percent of total QAS by method</u> (as indicated above), variables of the form <u>total QAS by method</u> (TQSP, TQSS, TQSI, TQSCN, TQSO - see <u>METHODS</u>, page 117 for descriptions) were also evaluated. Mean QAS (±S.E.) for Patrol, Stakeout, Investigation, Citizen Notification, and Other methods were 63.8±4.4, 11.2±1.4, 3.4±0.7, 9.7±1.1, and 1.4±0.4, respectively. Since no missing data existed for the latter measures, models tested with them had larger sample sizes than those including measures of percent QAS by method.

<u>Study Period</u>. Classification of all observations by study period was accomplished as intended.

<u>Effort</u>. A total of 8 observations reported no effort (total enforcement hours = 0.0) and were excluded from all AID and regression analyses since a dependent variable did not

exist for them.

Automatic Interaction Detection

In all AID analyses, the primary goal was to detect evidence of potential interaction among independent variables in explaining variance in the dependent variable, Total QAS/Hr. No predictors were forced into AID models, all variables were treated as monotonic classifications, and no ''Lookahead'' other than the normal 1-step tentative Lookahead was employed (see Sonquist et al. 1973). All AID runs specified a minimum group size of 10, excluded outliers, and employed the means analysis procedure.

A preliminary AID screening all personal background variables as potential interactors was tested. The resultant model explained only 12.9% of the total variation in the initial group (n=131). By order of entry into the model, i.e. ability to explain variance in the initial group and sub-groups, MILIYRS, SIGHT, JOFLEX, and PREVENF (see page 105 for descriptions) made 6 splits on the original group. Following graphic analysis of these splits and application of the criteria described in Methods, 3 variables (MILIYRS, SIGHT, and JOFLEX) involved in a 3-way interaction were selected for potential entry in the final AID run.

The preliminary AID screening of environmental attributes (not including TOTOTHHR) produced a final model which explained 26.0% of the variation in the initial group (n=371). By order of entry into this model, HUACCI, TOTRP, COMMERF, TOTFA, TOTHU, AVSPTK, AVDEHV, and AVFATK made 11 splits on the original group. Three variables (HUACCI, TOTRP, and COMMERF) were selected for potential entry in the final AID run.

The preliminary AID screening of methods of enforcement variables (TQSP, TQSS, TQSI, TQSCN, and TQSO) produced a model which explained 73% of the variance in the initial group (n=445). By order of entry into the model, TQSP, TQSCN, and TQSS made 6 splits on the initial group. All three met the criterion of splitting to groups of 15 or more observations and were therefore selected for potential entry in the final AID run.

The final screening for interactions was accomplished by only allowing those variables identified above plus TOTHR, TOTOTHHR, and study period to be candidates for entry. Thus, elimination of previously identified weak predictors provided an overview of interactions among strong predictors of all major categories of independent variables. Since TOTOTHHR was only available for May and August data, inclusion of this variable as a candidate reduced the sample size by approximately 1/2 and, in combination with the effect of missing data on SIGHT and

JOFLEX, the initial group size was only 140 observations. TOTOTHHR failed to enter this model so it was eliminated as a candidate and the AID analysis re-run. Elimination of TOTOTHHR (patrol area intensity of effort by other agents) as a candidate increased the initial group size to 239 observations. By order of entry, TQSP, TQSCN, and TOTHRS made 5 splits in the initial group (Fig. 4). No predictors from the personal background or environmental categories entered this model. AID output indicated that no close competitors existed at any split. Potential interactions detected were TQSP*TOTHRS, TQSP*TQSCN, and TQSP*TQSCN*TOTHRS (Fig. 4).

Fig. 4 illustrates the nature of these interactions. Observations were classified to categories 1-6 on each variable where class 1 was of low magnitude and class 6 of high magnitude. The first split shows that TQSP could explain variance in enforcement efficiency better than any other independent variable and that was done by grouping TQSP classes 1 and 2 into Group 1 and classes 3-5 into Group 2. No observations in the initial group were classified at TQSP class 6. The upper branch of the tree shows that TQSP class 2 was split by TOTHRS whereas TQSP class 1 was split by TQSCN. Thus, it can be concluded that the total QAS/enforcement hour of agents in TQSP class 2 is affected by effort (TOTHRS) differently than those of TQSP

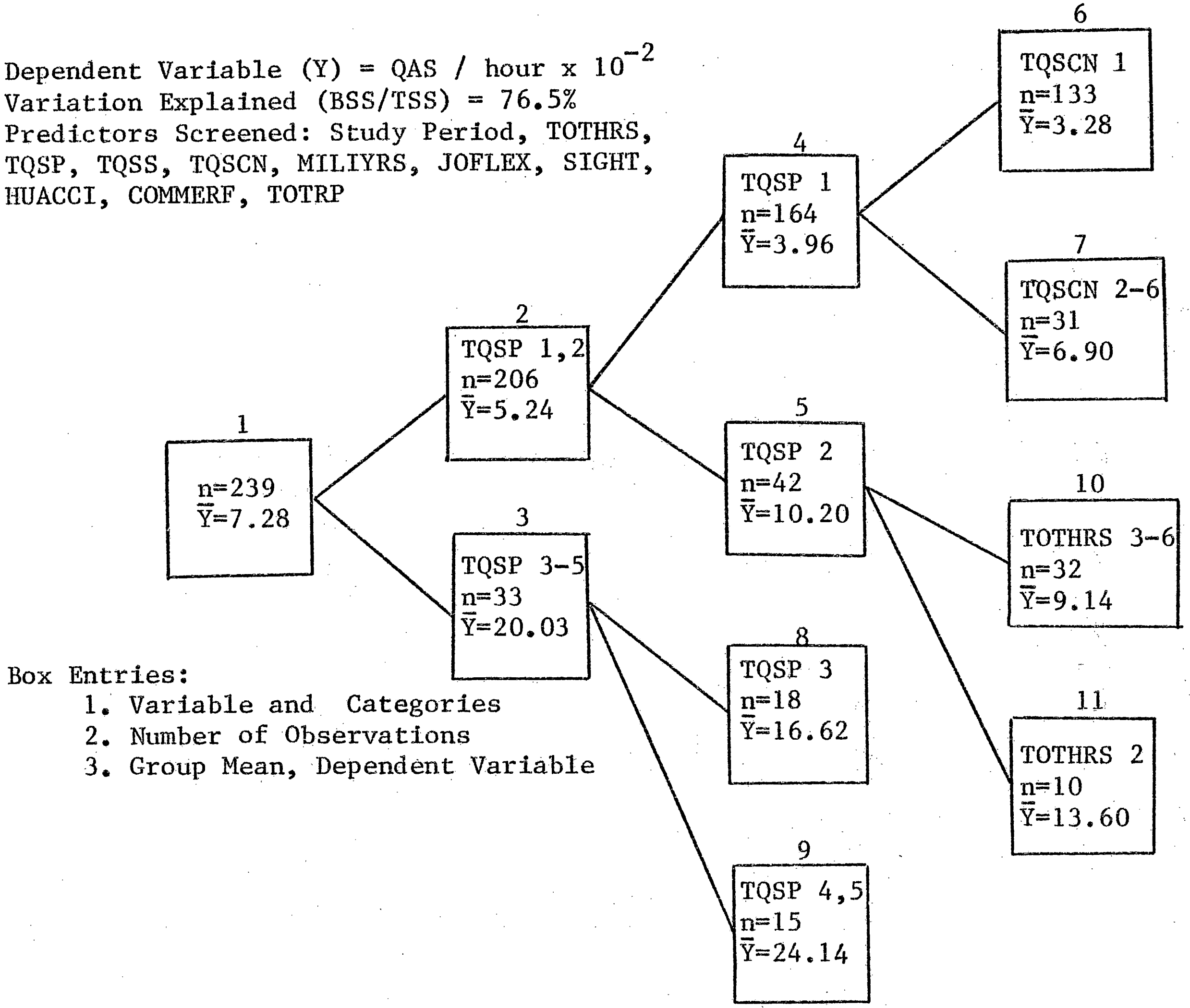

Fig. 4. Tree diagram from AID (Automatic Interaction Detection) among major independent variables of all categories.

classes 1,3,4, and 5. Also the total QAS/enforcement hour of agents in TQSP class 1 is affected by TQSCN differently than those of TQSP classes 2-5. The direction of the relationship of TQSCN with efficiency for all observations of TQSP class 1 is positive since the mean of the dependent variable increases as TQSCN increases (Note means of Groups 6 and 7, Fig. 4). However, a negative relationship exists between effort and efficiency in TQSP class 2 (Note means of Groups 10 and 11, Fig. 4). Thus, Fig. 4 suggests that change in effort or productivity by response to citizen notification will have unique effects on overall efficiency of agents who make lower quality scores by patrol as compared to those who make higher quality scores by patrol. Fig 4. also shows that major personal background variables and enviromental attributes have little if any interaction with other independent variables. Significance of interactions detected as described above were evaluated by subsequent analyses.

In summary, AID runs identified 3 major and several minor interactions as possibly occurring among independent variables. Due to the relatively small sample sizes, questions of stability of any interaction detected as described above could be raised. However, the purpose of the AID analyses was not to ascertain the statistical significance of the interactions (to do so by AID is impossible) but rather to identify them a priori to the building of regression models. This was particularly valuable in the present study because a large number of interaction terms would have to have been built into saturated regression models in order to evaluate all possible interactions.

Stepwise Multiple Regression Analyses

Interaction terms and all independent variables measured on an interval scale (metric variables) were subjected to screening by stepwise regression procedures in order to identify those variables to be entered in analysis of covariance models. Major and minor interaction terms subjected to this screening were HUACCI*TOTRP, HUACCI*TOTFA, HUACCI*TOTFA*COMMERF, TOTFA*COMMERF, HUACCI*TOTHU, MILIYRS*PREVENF, TQSP*TQSCN, TQSP*TQSS*TQSCN, TQSP*TQSS, TQSCN*TQSS, TQSP*TQSCN*TOTHRS, TQSP*TOTHRS, TQSCN*TOTHRS, PCTP*PCTCN, PCTP*PCTS*PCTCN, PCTP*PCTS, PCTCN*PCTS, PCTP*PCTCN*TOTHRS, PCTP*TOTHRS, and PCTCN*TOTHRS (see METHODS, pages 105, 112 and 117 for descriptions). All of these were detected during AID runs except for those involving percent of total QAS by method. The latter were patterned after the interactions detected in variables measuring QAS by method. All environmental attributes, all methods variables, effort, and all metric personal background variables (AGEAPP, AGEHIRE, MOSERV, LENRES, MILIYRS, YRSEXP, PREVENF, EXPERDIV, DIFFPOS - see METHODS, page 105 for descriptions) were included as candidates for entry in stepwise models. The stepwise procedure available on SAS (Barr et al. 1976) was used in these analyses. Parameters employed were an entry partial F level of 0.20 and a partial F rejection criterion of 0.15. No variable could enter the model if its significance level was greater than the former nor could it be retained if its significance level was greater than the latter. All data, dependent and independent variables, were standardized to a distribution of mean 0.0 and standard deviation of 1.0.

A preliminary stepwise analysis of all environmental attributes (except TOTOTHHR) as candidates (n=374) had a final multiple correlation coefficient of 0.11 with the entry and retention of AVBRHV, HUACCI*TOTRP, TOTRP, COMMERF, ACCPL, and HUACCI*TOTFA. A similar analysis including TOTOTTHR (n=213) as a candidate did not result in entry of this variable.

A preliminary analysis of all metric personal background variables as candidates (n=331) had a final multiple correlation coefficient of 0.05 with the entry and retention of only MOSERV, EXPERDIV, and DIFFPOS.

Two groups of final stepwise analyses were run.

First, models using percent of total QAS by method as enforcement methods variables were hypothesized. However, none of the resultant models had entry of those variables in them and because the multiple correlation coefficients were relatively low (less than 0.25) those variables were considered no further. Second, final models using enforcement methods variables of the form QAS by method along with all other metric candidates were tested. The latter analysis (n=280) yielded a multiple correlation coefficient of 0.94. Twelve variables were retained in this model including (by order of entry) TQSP, TQSI, TQSP*TOTHRS, TQSCN, TQSS, TOTHRS, TQSO, TQSCN*TOTHRS, TOWAREC, TQSP*TQSS, TOTAC, and AVDEHV (Table 22).

As a result of the stepwise screenings, TQSP, TQSI, TQSCN, TOTHRS, TQSS, TQSO, TOWAREC, AVDEHV, TOTAC, AVBRHV, TOTRP, HUACCI, COMMERF, ACCPL, MOSERV, EXPERDIV, and DIFFPOS were indentified as metric candidates for analysis of covariance models. All possible Pearson Product Moment correlations were computed to check for multicollinearity among these variables. If the absolute value of the correlation between any two was greater than 0.50 (indicating at least 25% common variance), one of the pair was eliminated from further consideration. Four pairs were found to exceed the 0.50 threshold, including EXPERDIV-DIFFPOS (0.89), TQSS-TOTHRS (0.52), AVDEHV-HUACCI (0.55),

Table 22. Mean squares and regression parameters from final stepwise multiple regression screening of metric independent variables. Dependent variable was QAS per enforcement hour.

Source of Variation[1]	DF	Mean Square	Level Attained[2]	Regression Parameter[3]	Standard Error
TQSP	1	53.20	0.0001	1.65	0.058
TQSI	1	37.76	0.0001	0.37	0.015
TQSP*TOTHRS	1	11.89	0.0001	-0.89	0.066
TQSCN	1	3.53	0.0001	0.34	0.046
TQSS	1	2.57	0.0001	0.17	0.028
TOTHRS	1	1.45	0.0001	-0.12	0.026
TQSO	1	0.92	0.0002	0.06	0.015
TQSCN*TOTHRS	1	0.62	0.0022	-0.15	0.049
TOWAREC	1	0.39	0.0147	0.04	0.016
TQSP*TQSS	1	0.32	0.0279	0.06	0.029
TOTAC	1	0.31	0.0296	-0.03	0.015
AVDEHV	1	0.26	0.0451	0.03	0.015
Regression	12	21.80	0.0001	-----	-----
Error	267	0.07	------	-----	-----

[1] See Methods for descriptions, pages 105, 112, and 117.

[2] Partial F test

[3] Intercept=0.0, R^2 = 0.938. Parameters shown are standard partials. Level of entry 0.20, rejection 0.15.

and COMMERF-ACCPL (-0.59). Therefore, HUACCI, ACCPL, and DIFFPOS were eliminated. Elimination of TOTHRS (total enforcement hours) would have excluded the only enforcement effort measure and since TQSS (total quality arrest score by stakeout) was shown as a potentially strong predictor in previous screenings, each was retained in spite of some potential multicollinearity between the two.

In summary, all enforcement methods variables, the enforcement effort measure, 7 environmental attributes, 2 personal background variables, and 3 interaction terms were selected as metric candidates for entry with discrete variables in analyses of covariance. These were TQSP, TQSI, TQSCN, TOTHRS, TQSS, TQSO, TOWAREC, AVDEHV, TOTAC, AVBRHV, TOTRP, COMMERF, MOSERV, EXPERDIV, TQSP*TOTHRS, TQSCN*TOTHRS, and TQSP*TQSS. Failure of TOTOTHHR (patrol area intensity of enforcement effort of other agents) to enter either the stepwise or AID runs indicates that the activity of other agents has little or no effect on the enforcement efficiency of each individual agent and thus this variable was considered no further. This latter result also shows that a major assumption regarding the independence of dependent observations (see METHODS) was upheld.

Analyses of Covariance

Table 23 shows the mean squares and regression parameters determined in the analysis of covariance of the full model formulated as described above. Caution must be applied in comparing the magnitude of regression parameters since sources of multicollinearity may inflate not only the coefficients but also their standard errors. However, mean squares of the partial reduction in error sum of squares are particularly useful since the main purpose of the analysis is to identify potentially important independent variables and is primarily of an explanatory nature.

Five variables were shown to dominate the full model in terms of the partial reduction of error mean square. These were, by order of magnitude of mean squares, TQSP (total QAS by patrol), TQSI (total QAS by investigation), TQSP*TOTHRS (the product of total QAS by patrol and total enforcement hours), TQSCN (total QAS by response to citizen notification), and TQSS (total QAS by stakeout) whose mean squares were all greater than 1.000 and shown as highly significant ($P<0.0001$) in the partial F tests. The error mean square with 276 degrees of freedom for this model was 0.067 (Table 23). TOTHRS (total enforcement hours) was also shown as highly significant although the mean square for this variable was only 0.903 (Table 23). Thus, as suggested by the AID and stepwise analyses, enforcement

Table 23. Mean squares and regression parameters from analysis of covariance of enforcement efficiency as affected by personal background characteristics, environmental attributes of patrol area, enforcement methods, study period, level of effort, and interactions.

Source of Variation[1]	DF	Mean Square	Level Attained[2]	Regression Parameter[3]	Standard Error
TQSP	1	41.592	0.0001	1.640	0.066
TQSI	1	33.142	0.0001	0.378	0.017
TQSP*TOTHRS	1	9.428	0.0001	-0.872	0.074
TQSCN	1	2.742	0.0001	0.327	0.051
TQSS	1	1.646	0.0001	0.155	0.031
TOTHRS	1	0.903	0.0001	-0.138	0.037
TQSO	1	0.753	0.0010	0.057	0.017
TQSCN*TOTHRS	1	0.518	0.0060	-0.147	0.053
TOWAREC	1	0.419	0.0133	0.046	0.018
TQSP*TQSS	1	0.250	0.0554	0.062	0.032
R 1	1	0.218	0.0733	0.280	0.157
MOSERV	1	0.217	0.0737	0.043	0.024
FIRED	1	0.184	0.0997	-0.161	0.098
R3	1	0.177	0.1063	0.242	0.149
R2	1	0.174	0.1083	0.248	0.154
AVDEHV	1	0.126	0.1734	0.025	0.018
TOTAC	1	0.075	0.2933	-0.022	0.021

Table 23. Continued.

Source of Variation[1]	DF	Mean Square	Level Attained[2]	Regression Parameter[3]	Standard Error
ED1	1	0.049	0.3921	-0.073	0.085
M2	1	0.027	0.5234	-0.043	0.067
M3	1	0.025	0.5434	-0.041	0.069
SIGHT	1	0.012	0.6706	0.027	0.063
AVBRHV	1	0.011	0.6886	0.007	0.019
TOTRP	1	0.010	0.6984	0.008	0.022
ED2	1	0.003	0.8240	-0.10	0.051
ED3	1	0.002	0.8559	0.009	0.054
COMMERF	1	0.002	0.8737	0.003	0.022
EXPERDIV	1	0.002	0.8537	0.004	0.024
M1	1	0.000	0.9799	-0.002	0.073
CON	1	0.000	0.9984	0.000	0.042
Regression	29	8.686	0.0001	------	-----
Error	239	0.067	------	------	-----

[1] See Methods for descriptions, pages 105, 112, and 117.

[2] Partial F test.

[3] Intercept = -0.22, R^2 = 0.938. Parameters shown are standard partials.

methods, effort, and their interactions show the strongest relationships with the dependent variable, enforcement efficiency. Only one environmental attribute (TOWAREC, patrol area intensity of water recreation) appeared to display a notable effect and this, by comparison to mean squares in Table 23, is only 1/100 (0.419/41.592) that of the strongest enforcement method variable (TQSP, total quality arrest score by patrol).

It should be noted that the partial F tests have the same level of significance as would be attained by tests of hypotheses that the regression parameters are equal to zero. Thus, it is quite apparent from examination of regression parameters, their standard errors, and the mean squares that AVDEHV, TOTAC, ED1, M2, M3, SIGHT, AVBRHV, TOTRP, ED2, ED3, COMMERF, EXPERDIV, M1, and CON have little if any relationship with the dependent variable.

A reduced model was then subjected to further analysis of covariance , eliminating the above identified weak independent variables. Table 24 shows mean squares and regression parameters obtained from this model. As would be expected, a general increase in the mean squares for most variables was effected. TOWAREC (patrol area intensity of water recreation) maintained a greater reduction in error mean square than the personal background variables, and whether the agent was an Officer or not (R1)

Table 24. Mean squares and regression parameters from analysis of covariance of enforcement efficiency as affected by major variables and interactions.

Source of Variation[1]	DF	Mean Square	Level Attained[2]	Regression Parameter[3]	Standard Error
TQSP	1	47.130	0.0001	1.635	0.060
TQSI	1	38.289	0.0001	0.381	0.016
TQSP*TOTHRS	1	10.303	0.0001	-0.871	0.069
TQSCN	1	3.404	0.0001	0.336	0.046
TQSS	1	2.423	0.0001	0.174	0.028
TOTHRS	1	1.292	0.0001	-0.127	0.028
TQSO	1	0.861	0.0003	0.058	0.016
TQSCN*TOTHRS	1	0.619	0.0023	-0.152	0.049
TOWAREC	1	0.563	0.0036	0.047	0.016
R1	1	0.415	0.0122	0.329	0.130
R2	1	0.328	0.0257	0.285	0.127
R3	1	0.300	0.0328	0.286	0.134
FIRED	1	0.228	0.0624	-0.158	0.084
TQSP*TQSS	1	0.224	0.0646	0.054	0.029
MOSERV	1	0.211	0.0727	0.035	0.019
Regression	15	17.266	0.0001	------	-----
Error	261	0.065	------	------	-----

[1] See Methods for descriptions, pages 105, 112, and 117.

[2] Partial F test.

[3] Intercept = -0.30, R^2 = 0.938. Parameters shown are standard partials.

was slightly more important than length of service (MOSERV) or whether the agent had been fired from previous employment (FIRED).

As indicated by inspection of mean squares, the estimated regression parameters (Table 24) also substantiate the conclusion that methods of enforcement were of greatest association to change in the dependent variable. The greatest ratio of change in the dependent variable per unit change in any independent variable was for TQSP (total quality arrest score by patrol). For TQSP this ratio was 1.635:1 and for TQSP*TOTHRS it was -0.871:1. Strength of TQSI and TQSCN (total quality arrest score by investigation and citizen notification, respectively) as indicated by the regression parameters were next in magnitude with coefficients of 0.381 and 0.336, respectively. However, as mentioned above, some regression parameters and standard errors may be affected by multicollinearity. Standard errors of the estimates were particulary large for R1, R2, R3, Fired, TQSP*TQSS, and MOSERVE. Examination of the correlation matrix of independent variables in this model showed absolute correlations greater than 0.50 for R1-R2 (-0.84), R1-MOSERV (0.53), TQSS-TQSP*TQSS (0.77), AND TQSP-TQSP*TOTHRS (0.93). However, most of the other inter-variable correlations were very low and the multicolinearities restricted to the variables identified immediately above. Examination of a residual plot showed no abnormalities indicating that a good fit was achieved and that homogeneiety of variance existed over the range of the dependent variable.

Since multicolinearity can affect the magnitude and sign of regression parameters as well as their standard errors, it is desirable to get a better estimate of the parameters of variables involved in multicolinearities than would be obtained by standard regression procedures. A frequent approach is to remove independent correlates from the model. However, this procedure is constrained to the extent that the researcher is interested in each individual variable being retained in the model. Thus, multicolinear variables may be left in the model due to their theoretical importance and the researcher incurrs, either knowingly or unknowingly, bias in the parameters. An alternative to the deletion of variables is the application of ridge regression procedures. This procedure biases diagonal values of the matrix X'X (see Equation 23) by a factor k prior to solution of the normal equations. It has been shown (Hoerl and Kennard 1970a, 1970b, Hoerl et al. 1975) that a vector $\underline{B}$ (Equation 23) can be estimated by ridge procedures which is a closer fit to the true parameters than would be estimated by standard regression procedures. In order to do so, a best estimate for k can be computed as

(Hoerl et al. 1975):

$$k = \frac{pS^2}{\underline{B}'\underline{B}} \qquad (27)$$

where: p = number of parameters

S^2 = error mean square of standard regression

$\underline{B}$ = vector of standard regression parameters

The solution for the ridge regression parameters is then found as:

$$\underline{B} = (X'X+kI)^{-1} X'\underline{Y} \qquad (28)$$

where: $\underline{B}$, X, $\underline{Y}$ are as in Equation 23,

k as in Equation 27,

I = an identity matrix of dimension equal to X'X

In order to attempt to develop regression parameters adjusted for problems of multicolinearity identified in the present study, a ridge regression was performed for the model shown in Table 24. Table 25 shows the results of the ridge regression. Regression parameters and standard errors were reduced for variables involved in multicolinearities, especially for TQSP, TQSP*TOTHRS, R1, R2, and R3. This vector of estimated regression coefficients can be considered a better fit to the true parameters than those of the standard regression which are affected adversely by multicolinearity. Examination of

Table 25. Regression parameters and standard errors of model of enforcement efficiency as determined by ridge regression.

Independent Variable[1]	Regression Parameter[2]	Standard Error
TQSP	1.607	0.061
TQSI	0.380	0.016
TQSP*TOTHRS	-0.839	0.070
TQSCN	0.335	0.047
TQSS	0.176	0.029
TOTHRS	-0.132	0.029
TQSO	0.058	0.016
TQSCN*TOTHRS	-0.152	0.050
TOWAREC	0.046	0.016
R1	0.283	0.121
R2	0.243	0.119
R3	0.237	0.126
FIRED	-0.157	0.086
TQSP*TQSS	0.049	0.030
MOSERV	0.032	0.019

[1] See Methods for descriptions, pages 105, 112, and 117.

[2] Intercept = -0.259, R^2 = 0.934, k=0.24035
Parameters shown are standard partials.

Table 25 shows again that methods of enforcement have the stronger association with the dependent variable than other independent variables. Magnitude of coefficients for R1, R2, and R3 are considerably larger than other personal background variables and the single environmental attribute of importance, TOWAREC (patrol area intensity of water recreation). However, standard errors on the coefficients of R1, R2, and R3 are still relatively large and thus caution must be exercised in comparing their magnitude to other variables.

In summary, it is to be concluded from these analyses that methods of enforcement (as they affect total QAS by method), especially patrol, are more closely associated with enforcement efficiency than are other major categories of independent variables studied herein. Preliminary stepwise regression and AID analyses suggested that environmental attributes of patrol areas may have a stronger relationship with enforcement efficiency than personal background characteristics of agents. However, final analyses of covariance showed rank as of potentially more influence than the single most important environmental attribute, an index of total water recreation (TOWAREC). Factors which have a negative relationship with enforcement efficiency include total effort expended (TOTHRS), an interaction of total effort and total QAS by patrol

(TOTHRS*TQSP, Fig. 4), an interaction of total effort and total QAS by response to citizen notifications (TOTHRS*TQSCN, Fig. 4), and whether or not an agent had been fired from previous employment (FIRED). Changes in all other major variables (Tables 24 and 25) were positively related to change in overall enforcement efficiency (total QAS/hr). These findings generally fail to support Ritter's (1975:46) hypothesis that the diversity of working conditions in Virginia counties may be related to agent effectiveness and tend to counter Cohen and Chaiken's (1972:15) suggestion that personal history data have promise as predictor's of good and bad performance.

CONCLUSIONS

The WILDSTRAT SYSTEM

Results of Research Goal I cleary demonstrate the utility of the WILDSTRAT SYSTEM in combining administrative experience and priorities with data on characteristics of patrol areas to develop optimal strategies for the deployment of enforcement manpower. The use of the system as applied for the direction of field operations or as a simulator to optimize long range planning has also been shown. The system is flexible enough to be applied in non-enforcement decision making such as for the distribution of extension agents, biologists, or other public service personnel.

As for any tool, the WILDSTRAT SYSTEM offers the potential for misuse. The system is not recommended for those agencies or administrators who do not wish to establish goals or goal priorities. For an administrator to be coerced to use such a system implies the agency is not ready for it and results from it would not be likely to affect field operations except in a negative fashion. Negative attitudes toward the WILDSTRAT approach may imply either an administrative satisfaction with other decision systems or an adversion to goal-setting, perhaps as a result of too many management workshops or organizational planning sessions. Satisfied decision makers would hopefully be those who presently utilize the best means of acquiring and processing information while simultaneously maximizing the objective and consistent use of their professional experience. It seems likely that the WILDSTRAT SYSTEM could do much to increase the satisfactions of those whose role is that of a decision maker. The wary administrator should recognize that the goal-setting necessary for WILDSTRAT can be as elaborate or as simple as the user desires. Examination of the test goals employed herein shows them of a quite high order; statements of broad intent rather than objectives with rigidly stated criteria of achievement. It is this investigator's hope that not many wildlife law enforcement administrators will be deterred by such goals and that the user will recognize that the relative importance of goals can be approximated even in the absence of rigid achievement criteria. Over time or in the more mature agency, they may be made progressively more precise.

Even after these assurances, the administrator may be hesitant to use WILDSTRAT because of lack of confidence in the methods of obtaining goal importance weights and activity effectiveness ratings. He may also be deterred by not having the required data on workload indices. To the first of these, it should be stressed that the <u>method</u> is not critical, any thoughtful method may be better than none. If the Churchman-Ackoff procedure and assumptions are unacceptable to an individual user, then any reasonable alternative method is feasible. For example, this study established goal weights in partial completion of Research Goal II by means of Thurstone's (1927) PC technique. This technique does not require assumptions of additivity of goal values such as does the Churchman-Ackoff procedure. However, it does rely on other assumptions which may not be applicable in certain situations. Employment of Thurstone's technique may lead to additional benefits because more than a select group of administrators would be involved in the goal-weighting process. The WILDSTRAT SYSTEM is not restrictive as to the method of evaluating goals or activities. Instead, it points the way to the need for such evaluations and offers valuable optional aids to performing them.

If the agency lacks data on relative workload among patrol areas, then it is sub-optimizing the expenditure of its limited resources. To not analyze data that has been obtained in an objective manner on workload yet still make decisions on manpower deployment is like the doctor prescribing medication for a fever without first taking the patient's temperature. One argument might be that the men in the field have an ability to assimilate all the necessary information and make the best decisions over that of any administrative direction. This may be true for a highly experienced and well educated agent in a relatively restricted patrol area, but it is unlikely that the chief has an unbiased perception of the distribution of all types of workload state-wide, or that a regional supervisor has an unbiased perception of all types of workload for a region encompassing dozens of patrol areas. Thus, it is very likely that an agency which would not use a decision aid such as WILDSTRAT due to data needs is the agency which needs it the most.

PRC/PMS (1974) made a valid criticism of approaches which rely on weighting of index variables in that few if any studies have shown crime occurrence to be related to physical or demographic variables. However, their criticism is valid only to the extent that deployment of an agent is directed to achieving a goal of modifying violation rates. Deployment intended to achieve other agency goals (other than reducing violation rates) through inspection of resource users, investigation of damage complaints, nonspecific patrol, public education, or other activities do not require the index be directly related to violation occurrence. If the goal is to deploy in direct relation to violation occurrence, then suitable indices exist for that very purpose (such as records of citizen reports of violations) and they should be used as such.

The matter of greater consequence is the assumption of a linear association between the workload index and the effort to be expended. To assume that effort is related to the amount of an index is reasonable, but to assume blindly that a linear association exists precludes the possibility that the effort necessary may be non-linear in relation to the index. For example, the total expenditure of effort to inspect 3 widely spaced boat landings may indeed be a linear function of the number of boat landings. On the other hand, if the boat landings are very close together and can be inspected visually from a single point, then the total effort expended may not be a linear function of the number of boat landings. The possibility of a nonlinear effort/index relationship does not preclude use of the WILDSTRAT SYSTEM, however. The user must be willing to develop models of the non-linear relationships that he suspects, and use the index to predict the effort that needs to be expended. The results of these predictions would then be input to the WILDSTRAT SYSTEM. Therefore, the degree to which the assumption of linearity is important to the user should mandate the degree to which he should develop non-linear predictions of effort expenditure. It is beyond the scope of this research to develop such models and, thus, the user's responsibility is stressed herein. It is not expected that this problem should inhibit preliminary applications of WILDSTRAT, and it is likely that future refinements will only improve its precision, not change major decisions.

An additional consideration is the assumption that effectiveness of agents is not adversely modified by movements between areas. Research Goal II of the present study was specifically intended to advance knowledge regarding the potential impact of making such an assumption when prescribing manpower movements. Based on the results of the correlational analyses performed herein, there appears to be an association between enforcement efficiency (total QAS/enforcement hour) and the intensity of water recreation in a patrol area. Since this was shown as a positive relationship, the decision maker could expect an increase in enforcement efficiency as manpower move into an area of intense water recreation or the reverse as movements are directed to areas of lower intensity. Therefore, if the WILDSTRAT user in Virginia had only a single goal, to maximize enforcement efficiency and personnel performed activities to this end alone, the only relevant workload index would be the intensity of water-related recreation in each patrol area. This is implied by the final regression analyses of Research Goal II which failed to show any other environmental attribute to have significant regression parameters, i.e. to have any marked relationship with total QAS per enforcement hour. To deploy manpower as described above would be an unrealistic method in existing systems since widely heterogeneous goals normally are in operation and since the importance of having an equitable distribution of manpower in relation to overall workload is perhaps far greater than a concern for a single (and relatively minor) influence on efficiency. The findings of this study that enforcement methods have a much greater relationship to enforcement efficiency implies that the administrator should be sure his agents are optimizing their enforcement methodology before he need be concerned with adjusting WILDSTRAT prescriptions according to known or suspected relationships between patrol area environmental characteristics and agent arrest efficiency.

An additional topic related to the use of this decision aid system but not addressed specifically by it is the need for optimal groupings of patrol areas into enforcement regions (districts) within which manpower transfers are made to meet workload variation. The concept of the enforcement region which consists of a group of patrol areas implies that intra-regional variability has been minimized and that inter-regional variablility has been maximized. This implication is inherent to the theory of regionalization; the reader is directed to Graf (1973) for a discussion of the topic. Graf (1973) developed an algorithm which considers all possible contiguous members of a set of wildlife management units (each analagous to the patrol area) and that identifies the optimal groupings within the set which maximize G, an index of regional (between groups) variability, where:

$$G = \frac{\text{Intergroup variability}}{\text{Total variablility}} \qquad (28)$$

To maximize G would group similar patrol areas into regions of maximum difference. An ideal application of the WILDSTRAT SYSTEM would be preceeded by a G-value analysis and design of enforcement regions in order to insure the best possible delineation of such regions. To do so would minimize the inter-patrol area variability within any region and thus minimize disparity in workload between the patrol areas of a region. Temporary manpower transfers between the patrol areas of a region would be less than would be expected for a enforcement system for which proper delineations were not made.

Technically, the WILDSTRAT SYSTEM could be applied over an entire state (i.e. a single ''region'') comprised of an unlimited number of patrol areas. This is quite feasible for the WILDSTRAT program for computing workload distributions, but the LOWCOST program would require massive computer storage requirements. A state with 100 patrol areas treated as a single region would require a linear programmming matrix with thousands of unknowns and hundreds of constraints in the latter algorithm. The probability of a problem of this magnitude failing to converge to an optimal solution would probably be high. Thus, regionalization facilitates the deployment decision process from both theoretical and mechanical standpoints. It is recommended that regionalization be done under the analytical methods, such as Graf's, which exist for that purpose. The WILDSTRAT SYSTEM and Graf's method of regionalization are compatible in that the data needs are exactly the same. An appropriate integrator of patrol area variation could be the workload proportions computed by WILDSTRAT.

A final point regarding use of the WILDSTRAT SYSTEM is the manner in which system outputs should be interpreted. As emphasized in a message to the user printed with LOWCOST output (Table 17), the manpower transfers prescribed are guidelines. The enforcement administrator should realize that the mathematical model employed in LOWCOST does not recognize a constraint or objective function expressed in terms of optimizing morale of field personnel, or in terms of maximizing confidence in its solutions. To deploy an agent 50 miles (80.4 km) to deliver 1 effective agent-hour to a demand patrol area according to the optimal least cost solution may actually be counter-productive in terms of personnel response to the system. Primary focus should be on major shifts of agent-hours exceeding some threshold amount. The level at which the threshold would be set would depend on the importance to the agency of achieving least cost goals as compared to non-economic personnel management goals.

Factors Related to Enforcement Efficiency

Of major interest regarding the analysis of factors related to agent productivity (total QAS/enforcement hour) is how the findings of this study relate to those of other research on law enforcement performance. The present study is unique in that most others have looked at only a single major category of factors affecting enforcement productivity whereas this study has attempted to evaluate several concurrently. However, others have had a wide variety of performance measures to evaluate whereas the present research was severely constrained in this regard. The measure selected is a major, if not the most important, enforcement productivity measure. Because these studies were the first of their type in the area of wildlife law enforcement they must be regarded as they were intended - as an exploratory search through a host of possible factors that might be related to enforcement efficiency.

Cohen and Chaiken (1972) , Ritter (1975), and others have raised the question as to whether findings which correlated personal background characteristics with performance were artifacts of influences such as on-the-job socialization, training, or environment. The results of this study suggest that most environmental factors as they relate to wildlife agent enforcement efficiency are relatively unimportant, especially as they compare to personal background attributes such as rank, previous employment history, and length of service. The significant negative relationship of the variable FIRED (whether an agent had been fired from a previous job) with enforcement efficiency indicates that of all the data present on job applications, it is the only variable which is of some predictive value. However, since this finding was based on the productivity measures of only 4 agents who indicated they had been fired from previous employment, this finding is definitely in need of verification. Perhaps of more significance was that differences in educational attainment prior to employment showed no relationship to later enforcement efficiency. Much conjecture abounds regarding whether agents with higher education are as qualified for wildlife law enforcement work as those who lack such training. One hypothesis suggested to the investigator by an enforcement chief was that agents with higher education may lack consistency in applying the law and therefore are not as productive as other less educated agents. The present study has not attacked the question of enforcement ''consistency''; however, it has produced no evidence that educational attainment prior to employment has any relationship to enforcement efficiency as defined herein. Although some observations were possibly affected by education obtained subsequent to employment as an agent, it is the investigator's opinion that this would be a relatively minor source of bias.

The finding that methods of enforcement as they affect total QAS by method (TQSP, TQSS, TQSI, TQSCN, and TQSO) were related to efficiency (total QAS/enforcement hour) is of particular interest. This finding was most evident for patrol and investigation (Tables 24 and 25). Since the relationships of efficiency with enforcement methods variables were positive, it can be concluded that efficiency will increase as productivity by an enforcement method is increased, particularly in the case of the patrol method. This finding may seem self-evident. However, it should be pointed out that an implicit and valid hypothesis predicating this research was that total QAS by any method and efficiency were both random variables and therefore there was no reason to expect any specific association.

There are two probable means by which an agent can increase his total QAS output by any method, (1) by increasing total effort expended in the method and (2) by becoming more proficient in applying the method. Since total effort (TOTHRS) was negatively associated with overall efficiency, and since there was a negative interaction between total effort and total QAS by patrol (TQSP), then to employ (1) without (2) would probably have an adverse impact on overall efficiency. In short, these findings suggest that patrol may offer the greatest potential for improving overall efficiency through change in apprehension effectiveness. Therefore, the wildlife law enforcement agent who would choose that method by which he might have the greatest opportunity for modifying his overall efficiency would be wise to select patrol. The relationship of stakeout with overall efficiency (Tables 24 and 25) was less than that of patrol or investigation. This finding is of relevance when one considers that the proportion of total effort devoted to stakeout, particularly in the fall, may be large. It should be cautioned however that these findings are the results of correlational studies of an existing enforcement system. If radical changes in such a system would occur, such as in methods of receiving or responding to citizen reports, then these findings may be invalidated.

The results of this study raise additional questions regarding the role of effort expenditure as it impacts efficiency. In need of further study is the relationship of time spent per method and efficiency by method. This research was not able to develop measures of time spent per enforcement method, nor is it entirely clear how this could ever be done. One way might be through subjective estimation but the potential for bias by that method seems high. Perhaps tightly controlled field experiments would provide a means for determining whether productivity in any particular method is a function of (1) or (2) above.

New Research Directions

Much additional work could be done in relation to the WILDSTRAT SYSTEM. Whether to embark on any additional development of the system should be determined in relation to the demand for use of the system. Should there be a spark of interest, the following extensions and improvements could be considered:

1. Incorporation of subjective probability estimation in developing stochastic linear programming solutions to manpower transfer problems. Risk assessments as they relate to financial and other costs could be entailed.
2. Incorporation of multiple-goal satisficing in regard to manpower transfer. Minimized deviation

from cost and enforcement efficiency criteria could be an objective function in a goal-programming formulation.

3. Improved efficiency of the existing algorithm. LOWCOST presently uses a linear programming approach which could be substituted with more efficient (computationally) transportation algorithms such as the northwest-corner method or Vogl's approximation method (VAM) (see Shamblin and Stevens 1974).
4. Field experiments assessing the impact of WILDSTRAT SYSTEM application on measures of enforcement efficiency, public perception of enforcement effectiveness, enforcement agency organizational dynamics, and personnel attitudes.

Also, additional research could be directed to the study of enforcement productivity:

1. Further study of the relationship of effort with productivity, as expended in each of several enforcement methods. See comments above.
2. Replication of the same research design as employed herein to provide validation of the results obtained by the present study. It would be preferable that such a replication be done in a different state in order to extend the

generalizability of research findings. Also, a multivariate approach where the dependent variable was a vector of productivity measures would be valuable. Inclusion of personnel evaluations, periodic reviews, or background investigations would be desirable.

3. Long-term ''in-house'' replication of the research mode used herein. Many problems related to non-response and acquisition of personal background data could be avoided if similar research was performed internally. Frequency of data collection and reliability of observations could be improved. However, improved data collection as could be obtained internally must be accompanied by adequate resources and research expertise.
4. Expanded development of enforcement efficiency measures, particularly in terms of QAS perceptions of wildlife agency personnel not in enforcement or of the general public.

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APPENDIX

Appendix I. Program Overview Questionnaire.

TO: John H. McLaughlin, Chief
Division of Enforcement, Virginia Commission of Game and Inland Fisheries

FROM: Cleve J. Cowles, Southeastern Wildlife Law Enforcement Research Project

RE: Wildlife Law Enforcement Manpower Deployment System

Please find enclosed the first of a series of questionnaires which will help to implement the deployment decision-aid system here in Virginia. As described in the paper, Dynamic Deployment of Wildlife Law Enforcement Manpower - A Decision Aid, subjective priority weights of goals and activity effectiveness are required as well as administrative designation of when each field activity of agents should be in progress. This first questionnaire is a follow-up to our discussions on 1 Sept. 1977. The intent is (1) to permit revision, if desired, of the preliminary goal and activity lists and (2) to rank order and assign priority weights to the set of goals. Although the assignment of priority weights to goals may seem a duplication of a previous survey, in this questionnaire we are primarily interested in administrator opinion rather than that of field personnel. The information you provide to these ends will be used in a trial run of the deployment system and be extremely valuable towards making the final product as useful as possible.

Please feel free to collaborate with your closest advisors in responding to the following questions. However, if desired, you may make a strictly independent response as the primary decision maker in your enforcement division.

PROGRAM OVERVIEW QUESTIONNAIRE

The following list of goals of the Enforcement Division were tentatively identified in previous discussions:

1. To assure that a desired level of resource use is obtained.

2. To attempt to distribute resource use or consumption equally among users.

3. To protect public and private property from harm as

a result of resource use.

4. To protect participating resource users from physical harm as a result of resource use activity.

5. To protect non-resource users from physical harm as a result of resource use activity.

6. To assure agency income by requiring users to pay for resource use.

Each of the below phrases is a shortened form of the above goals. The numbers correspond directly.

1. Maintain desired level of resource use

2. Maintain equal distribution of resource use

3. Protect public and private property from physical harm

4. Protect resource users from physical harm

5. Protect non-resource users from physical harm

6. Insure agency income

1(a). On the short form list of objectives above, please draw a line through any which you feel should be deleted due to their incompatibility with the goals of the Virginia Commission's Enforcement Division.

1(b) Please enter below any additional goal statements you feel should be included.

____

____

____

1(c). Now open the packet of cards in the white envelope. Note that 6 of the cards have the short form goal statement typed on them. Discard any card which you indicated in 1(a) should be deleted. On any of the blank cards write a shortened goal statement on the lines provided (preferably less than 10 words) corresponding to each addition indicated in 1(b). Write one statement per card, discard any un-used blank cards.

1(d). Now look through the set of goal cards. Arrange the cards in descending order of goal importance, the most improtant goal placed on top of the set of cards, the least important on the bottom. Your estimate of goal importance (priority weight) should be based on what you feel would be that of the Virginia Commission and/or public. In the box in the upper left corner (labeled "Goal Rank No.") of the most important goal, write the number "1". Number the remaining cards 2, 3, 4, . . .consecutively, most important to least important. If two goals are of equal importance, give them the same rank number. For example in a set of ordered goals a,b,c,d,e if "c" and "d" are of equal importance, the corresponding rank numbers would be 1,2,3,3,4.

Also, on card(s) No. 1 <u>only,</u> write the number 100 in the box in the upper right corner (labeled "Importance Score")

1(e). Spread the cards consecutively in front of you and assign an importance score to each of the goals numbered 2, 3, 4, . . . relative to the 100 assigned to the first goal. The number you assign must also be relative to that particular goal's rank number, thus goal 2 cannot be assigned a score of 100 since that is not less than the value assigned to goal 1. For example, if you feel that the goal ranked as no. 2 is very close in importance to the importance of the goal ranked as no. 1, you may assign a score such as 98 to goal 2. If goal 2 is considered half as important as goal 1, then a score near 50 may be appropriate.

The final result will be a set of cards numbered 1, 2, 3, 4, ... in the upper left corner, and containing a set of importance scores (in descending order) in the upper right corner. The latter set of importance scores represents the best estimate of relative importance among the goals.

1(f). Presented below is a preliminary list of activities which game wardens perform in order to help achieve the goals of your agency. The list has been developed as a result of our previous discussions. Please draw a line through any activity which you feel is not an activity performed by wardens in order to achieve the goals of the Virginia enforcement division. At the bottom of the list are several blank lines. Please state any activity not listed which you feel should be included.

The primary criterion for identifying an activity that should be included on this list is whether its performance contributes to the achievement of agency goals. We shall not be concerned with the relative contribution of activities now. We'll ask about that in a subsequent questionnaire. Also, the characteristics of an activity should be significantly different from those of the other activities listed. For example, inspection of muskrat trappers, mink trappers, raccoon trappers, etc., may be considered a subset of a primary activity "Inspect Trappers". Listing only "Inspect Trappers" would be justifiable from the standpoint that most patrol activity related to inspection of users of furbearer resources would tend to encounter all types of trappers in the principal locations patrolled. On the other hand, the activity "Inspect Deer Hunters" might be considered significantly different from the activity "Inspect Dove Hunters", due to both season and location.

In many of the activities listed, the term "Inspect" has been used. This implies not only the act of inspection of a certain user type, but also the performance of related activities such as patrol, investigation, stakeouts, etc., which normally are intended to bring the agent in contact with that specific resource user.

1. Inspect Cold-water Fishermen
2. Inspect Warm-water Fishermen
3. Inspect Boaters and Equipment
4. Inspect Bear Hunters
5. Inspect Turkey Hunters
6. Inspect Deer Hunters
7. Inspect Trappers
8. Inspect Squirrel Hunters
9. Inspect Dove Hunters

10. Inspect Waterfowl Hunters
11. Assist Stream Stocking
12. Investigate Damage Complaints
13. Inspect Game Check Stations
14. Teach Hunter Safety
15. Teach Boat Safety
16. Public Relations Speaking Engagements
17. Inspect License Agents
18. Inspect Boat Landings
19. Investigate Boating Accidents
20. Investigate Hunting Accidents
21. Inspect Special Permits
22. Perform Non-specific Patrol of Enforcement Area

23. ____

24. ____

25. ____

26. ____

27. ____

28. ____

29. ____

30. ____

After you have returned this questionnaire and the goal cards, we will send a second questionnaire which will provide a systematic basis for adjusting goal importance weights. These adjustments will be made relative to a series of paired comparisons among goals.

LOWCOST QUESTIONNAIRE

''LOWCOST'' IS A PROGRAM WHICH COMPLEMENTS USE OF THE ''WILDSTRAT'' PROGRAM. HOWEVER, IT CAN BE USED INDEPENDENTLY IF SO DESIRED. IT IS BEST APPLIED TO A SYSTEM WHERE MANPOWER IS LOCATED AT PERMANENT HEAD-QUARTERS AND WHERE AGENTS MAKE TEMPORARY MOVEMENTS FROM THESE HEADQUAR-TERS IN ORDER TO ACCOMPLISH WORK OBJECTIVES. THE LOWCOST ALGORITHM USES A LINEAR PROGRAMMING APPROACH TO PRESCRIBE TEMPORARY MANPOWER TRANSFERS. ASSUMING THAT OPTIMAL MANPOWER DISTRIBUTIONS HAVE BEEN OBTAINED FROM WILDSTRAT FOR A SET OF PLANNING PERIODS, THE USER NEED ONLY SUPPLY INFORMATION ON COSTS OF MANPOWER TRANSFER AND MAP COORDINATES OF CENTRAL POINTS OF PATROL AREAS. DISTANCES BETWEEN THESE POINTS ARE THE MAJOR DETERMINANTS OF THE COSTS OF MANPOWER TRANSFER, THE PROGRAM COMPUTES SOLUTIONS BASED ON THESE DISTANCES.

ALTHOUGH MANPOWER MOVEMENTS FROM POINT A EXACTLY TO POINT B MAY NOT IN PRACTICE BE EFFECTED, IN MOST APPLICATIONS THE USER SHOULD BE ABLE TO ASSUME THAT OVER A LARGE NUMBER OF DEPLOYMENTS FROM A TO B, THE DISTANCES MOVED WILL TEND TO AVERAGE OUT.

NOT ONLY CAN LOWCOST PROVIDE LEAST COST SOLUTIONS TO THE QUESTION OF HOW BEST TO MOVE PERSONNEL FROM SOME INITIAL DISTRIBUTION TO SOME DESIRED DISTRIBUTION, IT ALSO PROVIDES A POWERFUL SIMULATION TOOL. IN THE CASE OF WILDLIFE LAW ENFORCEMENT, MOST AGENCIES HAVE PERSONNEL DISTRIBUTED THROUGHOUT A STATE OCCUPYING PERMANENT RESIDENCES IN THEIR PRINCIPAL PATROL AREA. SINCE LOWCOST PROVIDES A SUMMARY OF ALL DISTRIBUTION PROBLEMS SOLVED IN A PARTICULAR RUN, THE USER CAN ASK THE QUESTION ''WHAT WILL BE THE EFFECT ON COST OF RE-ASSIGNING PERSONNEL TO NEW PERMANENT RESIDENCES OVER THE LONG-RUN?'' OR ''HOW WILL ASSIGNMENT OF NEW PERSONNEL TO THIS AREA AFFECT THE COSTS OF ACHIEVING OPTIMAL DISTRIBUTION PLANS?''. THUS, JUSTIFICATION ON

A COST BASIS CAN BE MADE FOR ESTABLISHING OR MAINTAINING CERTAIN HEADQUARTERED DISTRIBUTIONS. GENERALLY, THE MEAN OPTIMAL DISTRIBUTION, AVERAGED OVER ALL PLANNING PERIODS, WILL BE THE MOST COST EFFICIENT PERMANENT DISTRIBUTION OF MANPOWER. THIS MEAN OPTIMAL DISTRIBUTION IS PROVIDED ON PAGE 14 OF THE ''WILDSTRAT'' OUTPUT.

LOWCOST IS DESIGNED TO PROVIDE SOLUTIONS TO DISTRIBUTION PROBLEMS FOR DISTRICTS WITH UP TO 25 PATROL AREAS. IT CAN SOLVE LARGER PROBLEMS BUT MAY NEED SLIGHT MODIFICATION TO PROVIDE ADEQUATE COMPUTER STORAGE. IT PROVIDES TWO SOLUTION MODES, ONE WHICH COMPUTES EXACT SOLUTIONS REQUIRING MAXIMUM COMPUTER TIME AND ONE WHICH COMPUTES NEARLY EXACT SOLUTIONS REQUIRING MUCH LESS COMPUTER TIME. AN EXACT SOLUTION IS ONE IN WHICH THE TEMPORARY MANPOWER TRANSFER PRESCRIBED WILL MEET EXACTLY THE REQUIREMENTS OF THE ''WILDLSTRAT'' OPTIMAL DISTRIBUTION, ON A MAN-HOURS PER PATROL AREA BASIS. A NEARLY-EXACT SOLUTION IS ONE IN WHICH THE OPTIMAL DISTRIBUTION IN SOME PATROL AREAS MAY NOT BE ACHIEVED EXACTLY, BUT WILL BE OFF USUALLY BY ONLY A FEW TENTHS OF A PERCENT. FOR EXAMPLE, IF THE ''WILDSTRAT'' PROGRAM RECOMMENDS DEPLOYING 4.60% OF THE TOTAL MAN-HOURS TO COUNTY A FOR SOME PLANNING PERIOD, THE NEARLY EXACT SOLUTION FROM LOWCOST MIGHT PROVIDE GUIDELINES WHICH WOULD ACHIEVE 4.40% OF THE WORK FORCE IN COUNTY A. THE USER IS ENCOURAGED TO USE THE NEARLY-EXACT SOLUTION MODE. SINCE MOVEMENTS MAY HAVE BEEN ASSUMED TO BE DISTRIBUTED NORMALLY ABOUT SOME CENTRAL POINT OF EACH AREA, THE LOWCOST OUTPUT WOULD ALWAYS BE CONSIDERED AS A GENERAL GUIDE-LINE REGARDLESS OF WHETHER THE EXACT OR NEARLY-EXACT SOLUTION MODE IS SELECTED. ALSO, IT HAS BEEN FOUND THAT EXACT SOLUTIONS OF SOME PROBLEMS WITH LARGE NUMBERS OF PATROL AREAS MAY REQUIRE HOURS OF COMPUTER TIME WHEREAS THE SAME PROBLEM CAN BE SOLVED IN SECONDS USING THE NEARLY-EXACT SOLUTION MODE.

PLEASE FILL IN THE BLANKS BELOW IN ORDER TO USE LOWCOST:

1. DISTRICT NAME ____

2. NUMBER OF PATROL AREAS (COUNTIES) ______________________

3. YOU MAY SPECIFY THE PLANNING PERIODS FOR WHICH LOWCOST SOLUTIONS ARE DESIRED. ENTER THE APPROPRIATE PLANNING PERIOD NUMBERS INDICATING THE RANGE OF PLANNING PERIODS DESIRED. FOR EXAMPLE, IF THERE ARE 12 PLANNING PERIODS REPRESENTING JANUARY TO DECEMBER IN CONSIDERATION AND YOU DESIRE LOWCOST SOLUTIONS FOR JULY TO DECEMBER, ENTER 7 AND 12 BELOW.

FIRST PLANNING PERIOD IN RANGE _______

LAST PLANNING PERIOD IN RANGE _______

4. SOLUTION MODE DESIRED. CIRCLE ONE

NEARLY EXACT (0)   EXACT (1)

5. AVERAGE VEHICLE COST PER MILE, NOT INCLUDING DRIVER $_____.___

6. MEAL ALLOWANCE PER DAY OR AVERAGE EXPENDITURE PER DAY FOR MEALS

$___.___

7. LODGING ALLOWANCE PER DAY OR AVERAGE EXPENDITURE PER DAY ON LODGING WHEN LODGING IS NECESSARY $____.___

8. AVERAGE VEHICLE SPEED, MILES PER HOUR, IN TRANSIT DURING MAN-POWER TRANSFERS ________________

9. AVERAGE SALARY PER HOUR OF ALL AGENTS UNDER CONSIDERATION IN DISTRICT $____.___

10. AVERAGE NUMBER OF HOURS PER WORK DAY ______________

11. NUMBER OF WORK DAYS PER PLANNING PERIOD _______________

THE FOLLOWING QUESTIONS REFER TO THE PERMANENT LOCATIONS AND DISTRIBUTIONS OF MANPOWER AS INDICATED BY CURRENT HEADQUARTERS OF PERSONNEL.

FOR EACH PATROL AREA, IN THE SAME ORDER AS PRESENTED TO THE WILDSTRAT PROGRAM:

A. IN SPACE 1 ENTER THE ''X'' (HORIZONTAL) MAP COORDINATE FOR THE CENTRAL POINT (SEE U.S. GEOLOGICAL SURVEY MAPS, USE UTM OR DEGREES OF LATITUDE)

B. IN SPACE 2 ENTER THE ''Y'' (VERTICAL) MAP COORDINATE OF THE CENTRAL POINT (USE UTM OR DEGREES LONGITUDE)

C. IN SPACE 3 ENTER THE TOTAL MAN-HOURS PER PLANNING PERIOD PERMANENTLY DEPLOYED TO THE PATROL AREA. (E.G. 1 AGENT PER PATROL AREA FOR A WEEK MAY BE 60 MAN-HOURS)

D. IN SPACE 4 ENTER THE NAME OF THE PATROL AREA (COUNTY).

PATROL AREA	1	2	3	4
1.	____________	______________	_____________	_________________
2.	____________	______________	_____________	_________________
3.	____________	______________	_____________	_________________
4.	____________	______________	_____________	_________________
5.	____________	______________	_____________	_________________

Appendix III. Instructions for Summons Data Sheets.

ENFORCEMENT FACTORS STUDY

In the instructions below, the term ''arrest'' refers to the apprehension of a violator with subsequent issuance of a summons.

Instructions for Completion of Blue Data Sheets

Please look at the enclosed blue data sheets. In the upper right hand corner of page 1 are spaces for the provision of three data items, your state radio number, the month (which has been pre-recorded), and the total hours you spent in active enforcement during August. We would like to have your state radio number in order to be able to contact you in the case of any questions regarding the data sheet. Also, we can then determine the proportion of arrests which are made outside of counties to which officers are assigned. The information you provide will be compiled with that of the entire Division, will be kept in strictest confidence, and in no way will it used for individual evaluations.

After filling in the space provided for the state radio number, skip down to the main body of the sheet (Enforcement hours cannot be filled in until immediately prior to mailing the sheet to us).

The main body of each data sheet consists of two columns of blank spaces and five columns of boxes. Each row of blanks and boxes will be associated with a particular summons, thus the numbers 1 through 35 along the left margins indicate room for data associated with 35 summons. In the first column of blanks, under the heading ''VIRGINIA CODE NUMBER OF VIOLATION'', is a space for writing the Code number of the type of violation, such as 62.1-170, 29-51, etc. Write in this space the official code number of the law which was violated, exactly as done on the summons ticket. For example, if the violation was for fishing without a license you would write ''29-51'' in this space. If a certain section of a law was violated, include the appropriate identifying section letter. Please ignore the numbers in parentheses under each of the blank spaces in this column. These have been inserted in order to speed the data processing time.

In the second space (middle column, under ''COUNTY ARREST WAS MADE IN''), write the name of the county (not enforcement district) in which the arrest was made. This, of course, will not necessarily be the county of your residence.

In the 5 boxes under ''ARREST METHOD'' identify the method by which you made the arrest. One of these boxes (Labeled P, S, CN, I, or OT) is to be checked if the arrest was made during either patrol (P), during a stake-out (S), as a result of and following a citizen notification (CN), as a result of an investigation (I), or by some unusual or other (OT) method. Please place an ''X'' in the box corresponding to the method by which you made that particular arrest. The following definitions are provided for clarification:

Patrol (P) - Arrest made during random movement or movement of predetermined pattern through your enforcement area. Inspections and subsequent arrests are made incidental to this movement. The arrest was not made as a result of any prior information you received which would direct you to a specific site, violation, or violator. However, you may have patrolled the area because you anticipated general resource use and potential violations in that area.

Stake-out (S) - Arrest was made as a result of observation of an area while immobile and possibly concealed. Instead of moving through an area, you have remained motionless and let potential violators come to you. You were staked-out in that area because you had anticipated general resource use and/or potential violation activity at that location. The arrest was not made as an immediate result of prior information supplied by citizens or an investigation which directed you to a specific violation or violator.

Investigation (I) - Arrest was made as a result of analysis of detailed information obtained primarily through effort initiated by the officer. Usually would involve the analysis of a variety of evidence obtained by the officer which subsequently led to the arrest of a specific violator (although the identity of the violator may not have been known until the arrest was made). This does not include response to a single call directing you to the scene of a violation - See below.

Response to Citizen Notification (CN) - Arrest was made following the receipt of a notification initiated by a citizen and perhaps transferred to the officer by a dispatcher or other officer. Following receipt of such a message, you went to the scene and the arrest resulted shortly thereafter. The citizen's notification could have been made by telephone, in some written form, or in a direct conversation. The important discriminating characteristic is that a specific message was originally submitted to law enforcement agents by a citizen and there was a response to this specific notification. An arrest resulting from a message supplied by an informant would also be considered a citizen notification.

Other (OT) - This classification would be applied only to arrests which were made in some unusual method other than those described above. For example, while off duty a violation occurred near your home, you observed the violation, and made an arrest. It was not made during patrol, following an investigation, as a result of a notification, or during a stake-out and thus would be considered ''Other''.

It is obvious that you may have to make some difficult decisions regarding the classification of an arrest as to how it was made. For example, if you have been making an investigation for several months and a call tips you to making an arrest related to the investigation, the question would arise as to whether to classify the arrest as an I or CN. This would depend on your judgment of which methodology contributed to the arrest the most. In this case, if the arrest would not have followed the response to the call in the absence of the previous investigation, the appropriate classification would be I.

Shown below is an example in which the 5th arrest was for throwing litter into State waters, Virginia Code number 62.1-194. The arrest was made in Giles County during patrol. You will recall that the numbers in parentheses under the lines in the first column have no bearing on what you write on the data sheet.

****

EXAMPLE:

			P	S	I	CN	OT
5.	62.1-194 (68-76)	Giles	X				

****

Looking at the bottom of Page 4 of the data sheets, you will see several lines. These have been provided so that you can describe briefly the method by which you made any arrest classified as ''Other''. In the first blank space of this section copy the list number (1,2,...... or 35) of any summons classified as ''Other''. Then, in the second space provided, describe in a sentence or two the unusual circumstances.

Conclusion

The data sheets enclosed are to be used only for the month of August and should only include summons written during that month. Please list all summons written, regardless of whether court settlement is still pending for a particular case. Include only those for which <u>you wrote</u> the summons even in the case of an arrest made jointly by two officers. This will avoid duplication. It would be preferable that the data sheets be maintained in the field, as summons are written. Additional data sheets can be obtained from your district supervisor if needed. At the end of August following completion of your monthly activity book, compute from the book's Daily Activity Summary your figure for the total enforcement hours spent during August. This would be the sum of the Game, Fish, and Boat enforcement hours and would exclude hours spent in other activities such as Court or Public Relations. Then write this figure in the space at the top of Page 1 of the blue data sheets. When you are sure that the data sheets are filled in completely, please give them to your Area Leader. District Supervisors will then mail the data sheets from your district to our office in Blacksburg.

Thank you for your time in reading these instructions and in assisting with our data collection.

Appendix IV. Instructions for the Counties of Enforcement Activity Data Sheet.

Instructions For
Counties of Enforcement Activity Data Sheet

The purpose of the green data sheet is to record all counties in which you performed enforcement duties, including those in which you worked but made no arrests, during May. ''Enforcement duties'' refers to the performance of patrol, stakeouts, investigations, or response to calls related to law violations. You would also list any county in which you made an arrest while off duty. However, do not list counties merely visited while off duty or visited primarily for the purpose of public relations, safety instruction, administrative purposes, etc. Obviously you will have to again exercise a certain degree of judgment. For example, an officer driving through County Z on a Interstate highway in order to attend an administrative meeting in County X generally would not be considered performing enforcement under this interpretation since his primary purpose was to attend the meeting. An exception to his would be if he made an arrest while in transit or spent time, other than transit time, actually patrolling for potential violations.

Based on the above information, list in the first column under ''County of Enforcement Activity'' all counties in which you performed enforcement, including those in which you performed such activities but made no arrests.

In the second column, for each county, estimate the percentage of your total enforcement hours spent in each county listed. For example, if approximately 4 hours were spent in Giles County, 10 in Craig County, and 6 in Montgomery County, you would record 20%, 50%, and 30% for Giles, Craig, and Montgomery, respectively (Since the total hours was 20, 4/20 or 20% was spent in Giles, etc.). Please note that the total of all percentages you enter in column 2 must equal 100%. You may, if possible, compute the percentages directly as above. However, if you do not know the exact breakdown of hours spent by county, enter in column 2 your best estimate of the percentage of enforcement time spent in each county. The example is shown below:

County of Enforcement Activity	Percentage of Enforcement Time Spent in County
1. Giles	20
2. Craig	50
3. Montgomery	30
10.	
	Total 100

Please re-read the rest of the instructions and complete the remaining data sheets accordingly.

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OPTIMAL DEPLOYMENT OF WILDLIFE LAW ENFORCEMENT AGENTS WITH ANALYSES OF AGENT PRODUCTIVITY

by

Cleveland John Cowles

(ABSTRACT)

A decision-aid system for determining and achieving optimal distributions of wildlife law enforcement manpower was developed. Manpower distributions were computed by means of a workload formula for a case study application in the J.E.B. Stuart Enforcement District, Virginia Commission of Game and Inland Fisheries. A linear programming model was used to determine least cost methods of achieving prescribed manpower distributions. Simulations of permanent relocations and hiring of personnel were performed to evaluate the impact of management decisions on costs of achieving prescribed distributions. In the case study, total transfer cost resulting from simulated permanent relocation of personnel was 73% that of the present distribution, total transfer cost of simulated hiring of new personnel was 94% that of the present distribution. A simulation of inappropriate location of

new personnel resulted in an increase in total transfer cost of 22% over that of the present distribution. These findings were relevant only to the case study; however, the use of the system as a general purpose simulator was demonstrated.

Studies were performed of the relationships of patrol area environmental attributes, agent personal background characteristics, enforcement methods, enforcement effort, and season with enforcement efficiency (quality arrest score per enforcement hour). A wildlife law violation seriousness scale was developed in order to compute the measure of enforcement efficiency. Observations were obtained from Virginia wildlife law enforcement agents during November 1977, February, May, and August 1978. Patrol area intensity of 20 environmental variables, 25 personal background variables, 5 enforcement methods variables, total enforcement hours, and 4 study periods were independent variables. Two and 3-way interactions were detected by automatic interaction detection (AID) among total quality arrest score (QAS) by patrol, total QAS by response to citizen notification, and total enforcement hours. Analysis of covariance by multiple regression procedures indicated that methods of enforcement, effort, and their interactions were more closely associated with enforcement efficiency than other major categories of independent variables. Total QAS by patrol, total QAS by investigation, an interaction of total QAS by patrol and total enforcement hours, total QAS by response to citizen notification, total QAS by stakeout, and effort showed the greatest association with the dependent variable. To a lesser degree, agent rank, months of service, and whether the agent had been fired from previous employment were also shown to be associated with enforcement efficiency. Only one environmental attribute, the intensity of water recreation in the patrol area, was associated with enforcement efficiency. These results generally supported assumptions employed in the decision-aid system.