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POLICE ALLOCATION MANUAL

U S E R ' S G U I D E

Determination of the Number and Allocation of

Personnel for

Patrol Services for State Police Departments

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Prepared by

THE TRAFFIC INSTITUTE
Northwestern University

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SECTION 1: Introduction

Police Allocation Manual Project

The Police Allocation Manual User's Guide (herein after referred to as the Guide) is intended as a companion document to the Police Allocation Manual (PAM), Special Version, which can be used to determine the number and allocation of personnel for police traffic services for state police departments.

Both the Guide and the Police Allocation Manual (herein after referred to as the Manual) were developed by The Traffic Institute of Northwestern University under contract to the National Highway Traffic Safety Administration (NHTSA), U.S. Department of Transportation. A summary of project activities and products is contained in the Foreword. Additional information is available in the final reports submitted to NHTSA at the end of phases I, II, and III in February 1990, March 1991, and September 1991 respectively.

Police Allocation Manual Procedures

The procedures described in the Manual for determining the number of personnel are based on an analysis of trooper workload in terms of the amount of time required to complete various tasks. All trooper activities are assigned to four categories:

- Reactive: answering calls-for-service and responding to accidents;
- Proactive - Self-Initiated: traffic enforcement, field interrogations, motorist assists;
- Proactive - Uncommitted Patrol: patrol on uncommitted time; and
- Administrative: office time, vehicle maintenance, meal time, etc.

In PAM, the "Proactive-Uncommitted Patrol" workload category refers to uncommitted time only (i.e., time not spent on reactive, self-initiated, or administrative activities). Self-initiated activities that occur as a result of "uncommitted patrol" time are included in the "self-initiated" category. In other words, time spent looking for violators is defined as "uncommitted patrol time" while time spent with violators is defined as "self-initiated time."

The procedures used in the PAM model rely on historical data and user-supplied performance objectives. These data and objectives are used in nine worksheets in the Manual to guide the user through the process of determining how many troopers are needed for each of the categories identified above. For two of the categories, Reactive (Worksheet 3) and Proactive-Uncommitted Patrol (Worksheet 5), workload and performance objectives are used to derive the number of on-duty troopers required daily for each category. For the Administrative (Worksheet 2) and Proactive-Self-Initiated (Worksheet 4) categories, historical data and performance objectives are used to determine the proportion of trooper on-duty time that should be spent on activities in each category.

The results of the calculations in worksheets 2 through 5 are combined in Worksheet 6 to determine the average number of on-duty troopers needed each day. This result is further modified in worksheets 7 and 8 to account for the use of two-trooper units, minimum staffing levels, troopers used for special assignments, the number of field supervisors, the time-off policies of the agency, and the number of command and support staff. Worksheets 1 - 8 are used to obtain the staffing requirement for an "autonomous patrol area" (APA). The staffing requirement for an entire jurisdiction is obtained by adding the staffing requirements for all APAs in the jurisdiction. Worksheet 9 is used to allocate or distribute a total number of troopers among several patrol areas (APAs) or among distinct time periods or shifts for one patrol area. A complete description of the PAM methodology is presented in Chapter 2 of the Manual.

Contents of the User's Guide

The Guide consists of four sections and four appendixes. Section 1 ("Introduction") provides an overview of the PAM project and methodology, and the contents of the Guide. Sections 2 and 3 provide specific information and guidelines regarding "General Implementation Strategies" and "Data Definition and Collection Issues" respectively. The material in sections 2 and 3 is summa-

rized in a "Recommended Data Collection and Implementation Procedure" in Section 4. Appendix A contains a list of the data and performance information required for each of the nine worksheets in the Manual. Appendix B is a glossary of terms and notation used in Manual. Appendix C contains a detailed example in which each of the nine worksheets in the Manual is shown in completed form and Appendix D contains derivations of all of the important formulas used in the Manual.

How to Use the Guide

It is important to note that the Guide has been written for use as a reference document to assist both first-time and experienced Manual users. It is anticipated that no one will study this document section by section, front to back. Rather, it is expected that the Guide will be used as questions about data definitions, data collection, and the use of particular worksheets arise. First-time users will probably be most interested in the general implementation strategies discussed in Section 2 and the recommended procedure outlined in Section 4. More experienced users will likely find that they will refer to the information on data definitions and collection in Section 3.

SECTION 2: General Implementation Strategies

This section provides general observations about the implementation and use of the Manual for determining staffing requirements. All the observations are based on experience gained from field tests of the PAM procedures during both phases of the project. The first part below examines what the Manual can and cannot do. This is followed by suggestions for first-time users.

Uses and Limitations of the Manual

The calculations and procedures described in the Manual represent a "model" of police staffing; that is, the steps in the nine worksheets are based on mathematical and logical relationships between workload, patrol performance, the characteristics of the patrol area, and the total number of officers required. Analysts divide models into two broad categories: descriptive and pre-

scriptive. Identifying which category the PAM model belongs to is of use in recognizing how the model can be used and its limitations.

The PAM model is a prescriptive model; that is, using information about the workload, the desired performance levels, and the characteristics of the jurisdiction, the model can be used to "prescribe" how many officers are needed. The PAM model is not a descriptive (or predictive) model; that is, it is not possible to specify a fixed number of officers, the workload, and other characteristics of a jurisdiction and use the model to describe (or predict) what level of patrol performance can be expected. Similarly, it is not possible to use the PAM model to predict what the change in patrol performance or workload will be (e.g., the number of accidents to be handled) if the number of troopers is increased by a certain percent.

The prescriptive nature of the PAM model provides police planners with a powerful tool. Not only can the Manual be used to determine appropriate staffing levels for current workload, performance objectives, and jurisdictional characteristics, it can also be used to answer numerous "What if?" questions. For example, what will be the impact on staffing if the current workload increases by 20% or if the average travel time to accidents or other CFS is reduced by 1 minute?

Experience indicates that model "failures" can occur because of limitations of the procedure itself and from incorrect or unrealistic expectations by police planners about the capabilities of the model. The PAM model cannot provide the answers to all staffing and allocation questions; for example, as noted above, the model is not capable of predicting changes in performance as staffing levels change. Additional limitations are as follows:

- The PAM model cannot correct or compensate for inaccurate or incomplete data. This limitation is merely an application of the "law" most often associated with data processing and is summarized as GIGO; that is, "Garbage in, garbage out." At the same time, it is also true that the model is more sensitive to the accuracy of some data items than others. This fact is important in determining what level of effort should be expended in data collection. (See the discussion below in Section 4: "Recommended Data Collection and Implementation Procedure.")

- The PAM model can only prescribe how many officers are

needed when performance objectives are provided; that is, when someone or some group decides what level of service is desired. Stated in another way, the Manual is not a "silver bullet," that is, it is not a method for determining staffing levels that can be completed without management involvement or input.

- The PAM model cannot be used to predict the future workload (i.e., calls for service) of a patrol area.

- The PAM model, by itself, will not convince legislators or policy makers to increase funding support for additional staff. Decisions on staffing levels eventually reflect fiscal and political realities that transcend the specific methods used in any staffing procedure. The PAM procedures will strengthen requests for additional staff, but cannot guarantee their acceptance.

Guidelines for First-Time PAM Users

For persons who are using PAM for the first time, it is recommended that the steps outlined in Chapter 1 in the Manual (pages 1-2, 1-3, and 1-4) and the recommended procedure discussed in Section 4 below be carefully followed. The steps are:

- Read Chapter 2 in the Manual to gain an overview of the PAM model. (Some users may also want to review the material in Appendix D in the Guide.)

- Review Appendix A in the Guide.

- Review chapters 3 and 4 in the Manual with reference, as needed, to appendixes B and C in the Guide.

- Estimate the data collection effort.

- Assess the benefits of using the PAM model. (Only use PAM if the benefits to the agency outweigh the cost of the data effort.)

- Review the recommended procedure in Section 4 in the Guide.

- Collect the required data.

- o Complete the worksheets.
- o Review the results and adjust the input data.

Two important guidelines to remember, particularly for first-time users, are:

1. It is not necessary to complete all sections of each worksheet or even all the worksheets to obtain useful results.
2. It is not necessary to have highly accurate values for every input data item to obtain useful results. (See Section 4 below.)

The remainder of this section discusses the first guideline. Worksheets 1 - 8 in Chapter 3 in the Manual are used to determine the staffing level of an APA; that is, the "number" of troopers required. Worksheet 9 in Chapter 4 in the Manual is used to determine how the total number of troopers for several APAs should be "distributed" or "allocated" over the APAs. Worksheets 1 - 8 can be completed without completing Worksheet 9; and it is not necessary that the staff totals used in Worksheet 9 be calculated based on worksheets 1 - 8 if an alternative method for estimating staffing levels is available.

Within worksheets 1 - 8, it is possible to identify entire worksheets and sections of worksheets that may not need to be completed. If the PAM procedures are only used to determine the total number of troopers and field supervisors, section 8.4 dealing with the number of staff and command personnel can be ignored. If the PAM procedures are being used to determine onlythe average number of "on-duty" troopers required each day, then only worksheets 1 - 5 and Section 6.1 are needed. Even within these worksheets, not all sections are required. In Worksheet 2, the user must use either Section 2.1 or Section 2.2. In Worksheet 3, Section 3.1 can be skipped if the agency prefers to aggregate accidents with Other CFS (i.e., only use Section 3.2) or, alternatively, Section 3.2 can be skipped if the agency only responds to accidents (i.e., only use Section 3.1). In Worksheet 4, the user must use either Section 4.1 or Section 4.2 or Section 4.3; and in Worksheet 5, the user must use either Section 5.2 or Section 5.3. In Section 5.1, the user has the option of using as many or as few roadway types as appropriate for the APA.

Beginning with Section 6.2 in the Manual, the remaining sections and worksheets, which the user may elect not to use, provide adjustments to the average number of on-duty troopers required per day derived in Section 6.1. Sections 6.2 and 6.3 are used to account for agencies that use two troopers per unit for some patrols and for APAs with minimum staffing requirements. Worksheet 7 is used to account for troopers on special assignments and to determine the number of on-duty field supervisors required. Worksheet 8 is used to determine the total number of troopers and field supervisors (i.e., both on-duty and off-duty) and the total number of support and command staff required.

SECTION 3: Data Definition and Collection Issues

Data Collection Categories

As noted above, the PAM model requires that all regular trooper activities for patrol be classified into four categories. As a result, an essential first step in using the model is a "tailoring" process in which each type of trooper activity recorded by an agency is "assigned" to a particular category. While it is likely that all state-level law enforcement agencies will define and use similar kinds of activities in each category, it is also true that because of differences in operational practices and data definition and collection procedures, it is probable that no two agencies will define the data items to be included in each category in precisely the same way.

The lists below indicate the kinds of activities that were included in each of the categories by the field test agencies for the project.

Administrative Time

- o on-duty court time
- o training (less than one day)*
- o meals
- o auto maintenance
- o equipment maintenance
- o agency administrative duties
- o relay of equipment

- o roll call
- o briefings
- o report writing (if not put into reactive time)

* - Time off for training that requires one or more complete days can be included in the calculations for the shift relief factor in Worksheet 8.

Reactive Time (dispatches to accidents, criminal activities, emergencies, and non-emergencies)

- o travel time
- o on-scene time
- o report writing time
- o follow-up investigation
- o reactive time by all units dispatched
- o assists to other agencies
- o escort and relay
- o motorist assistance (if dispatched)
- o traffic control (if dispatched)
- o searches for missing and wanted persons
- o VIN verifications

Proactive Time - Self-Initiated Activities

- o traffic stops (traffic citations and warnings)
- o motorist roadway assistance
- o criminal investigation
- o traffic control
- o field interrogations

Proactive Time - Uncommitted Patrol

- o patrolling assigned roadways (includes both moving and stationary patrol)

The ability to tailor the PAM procedures to reflect the particular data collection practices of an agency is a strength of the model; that is, rather than requiring an agency to redefine existing data collection procedures to "fit" the model, it is possible to tailor the PAM model to fit the agency. At the same time, however, the flexibility that such tailoring permits requires that caution must be used when comparing the staffing estimates produced by the PAM model for different agencies; that is, unless both agencies use the

same data items, defined in the same way, in each activity category, it may not be possible to reliably determine the underlying causes for differences in staffing estimates between the agencies.

Experience to date indicates that decisions about which of the four categories each activity is assigned to have a relatively small impact on the final total staffing estimate. Far more important than the question of which category to use for each workload item is the need to insure that all trooper patrol workload activities are included and accounted for somewhere in the PAM model.

Selecting Autonomous Patrol Areas (APAs)

The PAM model estimates the total staffing for an agency by first determining the staffing levels for patrol areas using the following steps:

- The entire state is divided into a number of autonomous patrol areas. The APAs must cover the entire state and not overlap.
- The PAM model is used to determine the staffing level for each APA.
- The individual APA results are added together to obtain the staffing requirement for the entire state.

The selection of the APAs is dictated by the requirement that each APA should exhibit the following characteristics:

- Virtually all of the CFS that originate in the APA are handled by troopers assigned to the APA or, conversely, almost none of the CFS that originate in the APA are handled by troopers assigned to areas outside of the APA;
- Troopers assigned to the APA are rarely dispatched to CFS outside of the APA; and
- Although troopers may be assigned to patrol specific areas within the APA, troopers are routinely dispatched, as needed, to CFS anywhere within the APA.

The first two characteristics define what is meant by "autonomous." Simply stated, it means that the APA must be, for the most part, a self-contained or independent operational area with little or no cross-over of personnel either into or out of the area. (As a guideline, 90% of the CFS in the APA should be handled by units assigned to the APA.)

The third characteristic indicates that the APA cannot itself be a collection of smaller APAs; that is, all the units assigned to the APA must routinely be dispatched to CFS throughout the APA. If, however, units are only dispatched to CFS within their patrol areas and are rarely dispatched to CFS in other parts of the APA, then consideration should be given to dividing the APA into several smaller APAs.

The size of each APA within a state will vary depending on workload, population density, and traffic volume. From an operational perspective, APAs can be viewed as separate command areas, often characterized by the use of separate radio frequencies for dispatch. For some agencies, APAs may be defined by natural barriers; for example, a resort area that is separated from the rest of the jurisdiction by a large lake.

Worksheet Options and the Use of Performance Standards

To provide as much flexibility as possible, four of the worksheets in the Manual give the user two or three different ways to derive a particular value. The decision about which option to use in each case is based on the availability of historical data and the desire of the agency to set an operational performance standard as a matter of policy.

Occasionally, first-time PAM users are disappointed to learn that all the PAM calculations are not based on historical data and/or "national" standards for staffing or workload. (No such national standards exist.) Although, it is theoretically possible to use the PAM model based entirely on historical data, this is rarely done for at least two reasons. First, it is very difficult to collect all the required data, and second, use of historical data in all of the worksheets should yield staffing totals, assuming the model is valid and accurate, that will replicate the current staffing levels of an agency. While this may be useful in verifying the validity of the model, it is more likely that agencies are interested in examining the impact on staffing levels if one or more of the current workload, performance, or other data items are altered.

The remainder of this section briefly outlines the options explicitly available to the user in the worksheets. It should be noted that the term "explicitly" is used to highlight the fact that the user "implicitly" has options in determining every data item required by the model (i.e., the value used for each item can be selected by policy or can be based on historical data). For each of the options identified below, the decisions of the field test agencies regarding which option was selected and the average value selected or derived for each are shown in Table 1. (The data presented in Table 1 is based on 10 applications of the PAM procedures by the six field test agencies; that is, the PAM procedures were used for 10 different APAs.)

Administrative Time Per Trooper (Worksheet 2). Worksheet 2 permits the user to use either of two options (Section 2.1 or Section 2.2) to derive the average number of minutes per hour per trooper to be spent on administrative activities. Section 2.1 allows the user to set the average number of minutes as a matter of policy. Section 2.2 directs the user through the process of deriving the value based on historical data. Table 1 indicates that among the 10 field test applications during Phase III, 2 were based on Section 2.1 (Policy) and 8 were based on Section 2.2 (Historical Data). The average time based on historical data, 12.07 minutes per hour per trooper, was higher than the average of 9.75 minutes per hour per trooper based on policy.

Self-Initiated Time Per Trooper (Worksheet 4). Worksheet 4 permits the user to use any one of three options (Section 4.1 or Section 4.2 or Section 4.3) to derive the average number of minutes per hour per trooper to be spent on self-initiated activities. Section 4.1 allows the user to set the average number of minutes directly as a matter of policy. Section 4.3 directs the user through the process of deriving the average value based on historical data. (Sections 4.1 and 4.3 parallel the options provided in sections 2.1 and 2.2 in Worksheet 2.) The third option, described in Section 4.2, is a combination of the options available in 4.1 and 4.3. The derived value is based both on a policy decision (i.e., the average number of self-initiated contacts per shift per trooper) and the average time spent on each contact based on historical data. During the field test, 9 out of the 10 applications determined self-initiated time based on historical experience (Section 4.3). The average value for the 9 applications was 7.49 minutes per hour per trooper. (One application used the policy-indirect option in Section 4.2 and obtained a value of 9.80 minutes. Some field test agencies were hesitant to use the policy options out of concern that they could be interpreted as a system of enforcement "quotas."

Uncommitted Patrol Availability (Worksheet 5). Worksheet 5 gives the user two options (Section 5.2 and Section 5.3) for determining the number of on-duty troopers needed per day for "uncommitted patrol availability." This value is then compared with the average number of troopers needed for "uncommitted patrol visibility" (Section 5.1) to derive a total number of on-duty troopers needed per day for "proactive-uncommitted patrol." Section 5.2 is used to determine the number of troopers needed to have enough units available to respond immediately to a specified percentage (provided by the user) of all accidents and CFS. Section 5.3 is used to determine the number of troopers that are needed to provide an average travel time to reactive activities. The average travel time objective is set by the user. The calculations in Section 5.3 (steps 5.3.1 through 5.3.6) assume area patrol (i.e., patrol units have responsibility for responding to calls throughout a geographic area). If line patrol (i.e., patrol units have responsibility for a specific roadway segment only) assignments are also used, the number of troopers required is calculated in a supplemental worksheet in Appendix B and entered into (5.3.7). Table 1 indicates that most applications (i.e., 9 out of 10) for the Phase III field test used Section 5.2. Five agencies also examined the area patrol option (Section 5.3), but none used the line patrol option in Appendix B.

Strategies for Controlling the Data Collection Effort

Use of the PAM model for one APA can vary in difficulty depending on the availability of data and the amount of work required to

obtain the data. When all the APAs for a state or for even parts of a state are considered, the magnitude of the data collection effort required may be significant. For agencies that may elect to use several APAs, the field test experience revealed two strategies that agencies can use to limit this effort.

APA-Independent Data. There are a number of input data items required in the model that are largely independent of the location or other attributes of each APA, and as a result, it may be possible to use one value for each data item for all APAs. Although the specific data items will vary from one agency to another, the following list should apply to most:

- average number of on-duty hours per year per trooper,
- average number of troopers per field supervisor,
- average fraction of time spent on patrol by field supervisors,
- average service time for accidents,
- average service time for other CFS,
- percent of units with two troopers,
- average time per hour spent on administrative activities per trooper
- average time per hour spent on self-initiated activities per trooper, and
- shift length.

APA-Dependent Data. There are also a number of input data items that will likely vary by APA within the same state. A partial list would include:

- number of roadway miles by roadway type,
- number of accidents and other CFS,
- amount of patrol coverage by roadway type,
- average patrol speed by roadway type,
- patrol interval by roadway type,
- immediate response percentage,

- o average response speed,
- o average travel time,
- o amount of patrol available from troopers on special assignment, and
- o presence and influence of minimum staffing limits.

During the Phase I field test for state-level agencies, several sites were able to control the data collection effort for APA-dependent data by recognizing that most data items that vary by APA are related to the proximity of the APA to urban or rural areas. Recognizing this, groups of APAs were categorized by their "urbanicity" and identical input data values were used for all APAs in the same category.

Discussion of Individual Data Items

The PAM model estimates the required staffing level for an APA by accounting for all the time that troopers need to perform patrol activities. The PAM model (Version S3.0) uses four time categories and general definitions about what activities are associated with each category. It is important to note, however, that the current model represents only one way out of many that could be used to categorize and define patrol activities. The significance of this observation is that regardless of what categories and definitions are used, they must account for all patrol activities. As expected, the field test provided considerable feedback about a number of data definition and data collection issues. This section provides an overview of some of the data-related issues that arose during the field test.

Immediate response percent. The immediate response percent is used in Section 5.2 to determine how many on-duty troopers are needed each day to insure that a trooper will be available for immediate assignment for a given percent of all accidents and other CFS. It is important to note that "immediate" response is not the same as "rapid" response. Immediate response merely implies that at least one trooper will be available, somewhere in the APA, for the assignment. No consideration is give to how far away the trooper may be from the incident. Users that are interested in the number of troopers that are needed to maintain a user-specified average travel time in responding to incidents should use Section 5.3. Table 1 indicates that the immediate response option in Section 5.2 was used in 9 of the 10 field test applications and the average value selected was approximately 85 percent.

On-duty hours on patrol per year per trooper. The average number of on-duty hours per year per trooper is used in Section 8.2 to calculate the "shift relief factor" (SRF). The shift relief factor indicates how many troopers are needed to cover one shift position every day. For 8-hour shifts, SRFs typically range from 1.60 to 1.90; i.e., for each shift position, a total of 1.6 to 1.9 troopers is needed. A common question is whether the average number of on-duty hours per year per trooper equals 2,080 hours obtained by multiplying 52 weeks by 40 hours per week. The answer to this question is no. The 2,080 hours equals the number of hours for which a trooper is "paid" for one year and is greater than the number of on-duty hours because it includes paid "time off" (e.g., vacations and holidays). The average number of on-duty hours on patrol per year per trooper is the number of hours each trooper is actually on patrol duty, not on the number of hours for which the trooper is paid.

Although it is easy to see why "benefit time off" like vacations and holidays should not be included, there are other situations in which the definition of "on-duty" time is more difficult to interpret. The difficulty arises because not all on-duty time is spent on patrol (i.e., temporary special assignments may remove an officer from regular patrol duty). As an example, consider a trooper who is sent to a two-week training program. An administrator may argue that the trooper is "on-duty" whether he/she is on patrol or at a training program. A patrol commander, on the other hand, may argue that when the trooper is gone for two weeks, there is a staffing shortage on patrol that is just as real as if the trooper were on a two-week vacation. From the commander's point of view, the trooper is not "on-duty" in the sense that he/she is not on patrol, and as a result, the two weeks spent at training should not be included as on-duty time. There is no one "right" way to define on-duty patrol time; it depends on the policies and practices adopted by each agency. Since the definition used to calculate SRFs may vary from one agency to another, the following guidelines should be noted:

- The calculation of the shift relief factor in Section 8.3 requires that a definition of "on-duty patrol" time, appropriate for the agency, be adopted; and

- The comparison of shift relief factors for different agencies is not appropriate unless the same definition of "on-duty patrol" time is used by both agencies.

Table 1 indicates that the average value for on-duty time per year per trooper was 1,810.27 hours that, assuming 8-hour shifts, produces a SRF of 1.61 troopers per shift position.

Patrol coverage. Patrol coverage is used in Section 5.1 to calculate the number of on-duty troopers required each day to meet a user-specified patrol interval. Patrol coverage refers to the number of hours per week that an agency will provide services in an APA or on a roadway segment. (The maximum coverage is 168 hours per week.) Patrol coverage is a policy decision and represents an either-or situation (i.e., either coverage is provided or it is not). Patrol coverage does not identify the level or intensity of coverage for a particular area; this is indicated by the "patrol interval" discussed below. Table 1 indicates that patrol coverage was approximately the same for all roadway types; the average was about 140 hours for each of the three categories. (Care must be taken in interpreting field test results based on roadway categories since each agency was free to define roadway types to fit the characteristics and data availability of the APA in its jurisdiction.)

Patrol interval. Patrol interval is used in Section 5.1 of the Manual as a measure of the level or intensity of patrol coverage. It is measured in hours and indicates the average time that a stranded motorist would have to wait to see a trooper come by on free patrol (i.e., proactive-uncommitted patrol). As an example, a patrol interval of one hour means that a motorist, stranded on the roadway, would have to wait an average of one hour before seeing a trooper. While there is no theoretical upper limit to the patrol interval, the largest value used during the field test was 168 hours (i.e., a motorist would have to wait for one week). Table 1 indicates that the average patrol interval for category 1 roadways for the field test was only 6.40 hours. For category 2 roadways, the average was 13.20 hours, and for category 3 roadways, the average was 20.40 hours.

Patrol speed. Patrol speed is used in Section 5.1 as part of the calculation to determine the number of on-duty troopers required to meet a specified patrol interval. Average patrol speed and average response speed (discussed below) are often among the most difficult data items to obtain for use in the PAM model. A number of different approaches can be used to estimate this value:

- Use of log sheets. Average patrol speed equals the total number of miles driven while on "patrol" divided by the total time spent on "patrol." The mileage and time estimates must be based on "proactive-uncommitted patrol" as defined in the PAM model; that is, only mileage and time spent on uncommitted patrol (including stationary patrol) should be used for the calculations. Any mileage accumulated for or time spent on activities that fall into any of the non-uncommitted patrol categories (i.e., administrative, reactive, and self-initiated) is not included.

- Ride along observers. Some agencies have attempted to estimate average patrol speeds by having observers ride along with troopers while on patrol. Experience indicates, however, that the presence of an observer may cause changes in driving behavior.

- Survey of troopers. Another approach is to survey troopers to obtain an estimate of the average speed. Use of this method, however, is often questioned since experience indicates that human recollection is often not very reliable in estimating "average" speeds. (There is a tendency to remember only the cruising or top speed and to forget times when a unit is either stationary or moving very slowly.)

In the last section of the Guide, a general approach to using the PAM model is outlined. One of the important suggestions is that users must exercise judgment in determining how accurate each input value should be and how much effort should be expended in obtaining each item. Patrol speed is a data item that can, if one is not careful, require far more effort than may be justified by its contribution to the final staffing estimates. In Table 1, the average patrol speeds used by the field test agencies were 39.45 MPH for category 1 roadways, 27.47 MPH for category 2 roadways, and 19.22 MPH for category 3 roadways.

Response speed. Response speed is used in Sections 5.3 to estimate the number of on-duty troopers required to provide a response capability that maintains a user-specified average travel time. Like patrol speed, this data item may be quite difficult to obtain. The same procedures that were outlined above for determining patrol speeds can also be used to estimate response speeds with all the corresponding difficulties associated with each of the procedures. (If log sheets are used, mileage and times must be based on travel to reactive incidents only.) In fact, the influence of ride-along observers and the unreliability of personal recollection to estimate response speeds may be even more pronounced. PAM users are strongly encouraged to follow the recommended data collection strategy outlined in the last section of the Guide to avoid unnecessary effort spent on obtaining response speed estimates. In Table 1, the average response speed (over all roadway types) is 36.27 MPH for area patrol.

Roadway types. To use the PAM procedures in Section 5.1, the user must define three roadway types for the APA. As an example, all roadways in the APA could be divided into primary highways, rural highways, and residential streets. The user must also indicate how many miles of each roadway type there are in the APA. These cate-

gories are used in Section 5.1 for the derivation of the number of on-duty troopers needed each day to meet the patrol interval objectives set by the user for each roadway type. PAM users are not required to use any particular set of roadway categories or to use exactly three roadway types. To accommodate data collection procedures within their state or agency, users may want to use a different number of roadway types. The critical issue is not whether three roadway types are used, but rather that all roadway types and miles routinely patrolled in the APA are included in the procedures for deriving agency staffing estimates. The selection of how many roadway types and how each should be defined will vary from agency to agency. It is recommended that definitions be used that rely, to the extent possible, on the following factors:

- traffic volume on the road,
- use of the road (i.e., feeder, collector, throughway, etc.),
- average speed on the road,
- need for police patrol on the road, and
- the availability of traffic and operational data by roadway type.

Self-initiated time. Worksheet 4 is used to determine the average number of minutes per hour per trooper for self-initiated activities. In PAM, self-initiated activities refer to activities initiated by a trooper rather than directed by the dispatching center. It is important to note that the distinction between reactive and self-initiated activities is not determined by what is done but rather by the manner in which the activity is initiated. As an example, if a trooper is directed to a particular location to control traffic because of a fallen tree on the roadway, the time spent on this activity would be charged to reactive time. If, on the other hand, the trooper discovers the fallen tree while on uncommitted patrol and determines that he/she should control traffic until the tree can be removed from the roadway, this time would be assigned to the self-initiated category. Table 1 indicates that no field test agencies determined the average self-initiated time by policy. When based on a specified number of contacts per shift and the average time per contact, the average self-initiated time was 9.80 minutes per hour per trooper. When based solely on historical data, the value was 7.49 minutes per hour per trooper.

Service time. Average service times for accidents and other CFS are used in Worksheet 3 to determine the average number of on-duty troopers needed each day to handle the "obligated" workload. Ser-

vice time refers to the total spent on an incident by all agency patrol personnel. Service times should include:

- travel time (not including dispatching time),
- on-scene time,
- report writing time,
- investigation time (by patrol),
- processing time (e.g., for DUIs), and
- time spent by backup units.

In Table 1, the average service times for accidents and other CFS are 1.88 hours and 0.87 hours respectively. Few agencies have data collection procedures that capture all the components of service time listed above. Many CAD systems, for example, will capture the travel, on-scene, and possibly some follow-up time of the category 2 unit dispatched to an incident, but may not capture report writing and time spent by backup units. Some agencies do not routinely record the frequency and amount of time spent by backup units although backup time can represent a significant part of the total obligated time for an agency. If an agency plans to use operational data captured by a CAD system, it is recommended that the specific definitions built into the system be examined to detect possible shortcomings in the data summaries produced by the system. Recognizing that few agencies routinely capture all the components of service time, it is likely that most PAM users will have to estimate all or part of the average service times they use in the PAM model. Reliable estimates for average service times do <u>not</u> require that information be obtained from all incidents. (In fact, this is not realistic since incident records are often incomplete.) A reliable value for the average service time for a particular incident category can be obtained by randomly drawing a sample of 100 or more incidents in the category for the period of interest.

In Worksheet 3, total obligated time for an agency is determined first by calculating the total obligated time required for all accidents and then using that time to determine the total number of on-duty troopers needed each day to handle accidents (Section 3.1). The same procedure is used in Section 3.2 to determine the total number of on-duty troopers required each day to handle all other CFS. The results are then added together in Section 3.3 to obtain the total number of on-duty troopers needed each day for both accidents and other CFS. The PAM model separates accidents and other CFS to enable the user to identify explicitly the number of troopers required for each type of incident. During the PAM field test, some agencies did not use both categories in Worksheet 3, but de-

cided instead to group all incidents in either the accident or the other CFS category. This procedure will yield the same total number of on-duty troopers if an adjusted average service time based on both types of incidents is used.

It is also possible to use more than two CFS categories. For example, the collection of all "other CFS" can be divided into several subcategories and each subcategory can be used to determine the number of on-duty troopers that are needed each day to handle all the calls in that subcategory. (To use this procedure, however, requires that an average service time must be estimated for each subcategory.) The total number of troopers required is obtained by adding the trooper requirements for each subcategory together. While the use of subcategories provides additional information about which types of incidents require the most personnel, it has no impact on the total staffing level required for all incident types collectively. As a result, the value of the additional information must be weighed against the extra effort required to collect incident data by subcategory and to estimate an average service time for each.

Shift length. The PAM procedures are designed to accommodate any shift length (e.g., 8 hours, 10 hours, or 12 hours). Changes in the shift length will alter the shift relief factor for an agency. For 8-hour shifts, SRFs typically fall into the range: 1.60 - 1.90. For 10-hour shifts, the range is 2.00 - 2.40; and for 12-hour shifts, the usual range is 2.40 - 2.90. A common misperception is that since a change in the shift length changes the SRF, it must also change the total staffing requirement for an agency. This is not true. In fact, if the average work week (e.g., 40 hours per week) and the total time off given for benefits (e.g., vacations, holidays, etc.) remain the same, a change in shift length has no impact on total staffing.

Special assignment personnel. Special assignment personnel who are also used for patrol can be included in Worksheet 7 of the Manual. For each type of special assignment, the user must provide the total number of troopers used for that assignment in the APA and the average fraction of time each trooper spends on patrol. This information is then used to adjust the total number of "non-special assignment" troopers that are needed and the final staffing value from Worksheet 7 includes both the special and non-special assignment troopers. The PAM model, however, cannot be used to estimate how many troopers will be needed for special assignments (e.g., accident investigation and hazardous materials).

Staff and command personnel. Section 8.4 in the Manual is used to include the number of staff and command personnel for the APA. The value is supplied by the PAM user. It is not necessary, however, to use this section to obtain estimates for the number of troopers

and field supervisors that are required; these values are obtained in Section 8.3.

Travel time. In Section 5.3 and the supplemental worksheet in Appendix B (in the Manual), the PAM user must provide a travel time objective as part of the procedure for determining how many on-duty troopers are needed for area and/or line patrol. Travel time refers to the time interval that begins when a trooper receives a dispatch and ends when he/she arrives on scene. Travel time does not include dispatching time (i.e., the time required at the communication center to process and transmit the assignment to the trooper). It is also important to note that the travel times required in Section 5.3 and Appendix B are "averages." This means that the actual travel time will be less than the user-specified average about half of the time and greater than the average for the other half. In Table 1, the average travel time objective selected for the field test for area patrol was 5.35 minutes. No field test agency used the line patrol option.

SECTION 4: Recommended Data Collection and Implementation Procedure

The bulk of the work associated with using the PAM procedures involves defining and collecting data, and unless caution is exercised, it is possible to be overwhelmed by these activities. This section of the Guide presents a recommended procedure for using the PAM model that is designed to avoid excessive data collection efforts. The recommended procedure is based on the successes and problems encountered by the six sheriff's departments in the Phase III field test. The procedure consists of four steps that describe an iterative process for using the PAM model.

STEP 1: Obtain Initial Staffing Level Estimates With Minimum Data Collection Effort

It is likely that every agency that uses the PAM procedures will find that it does not have all the input data that is required. This may occur for several reasons: the agency does not routinely collect the data; the agency collects the data, but not in the form or categories required; or the data is collected but not stored in an easily retrievable form. Whatever the reasons, every agency will be faced with the question of how much effort to expend in obtaining each data item. Step 1 recommends minimizing the initial data collection effort; that is, for input data items that are not easily obtained, "quick and dirty" estimates or guesstimates should

be used. The rationale for this recommendation is that it is more important to obtain an initial estimate of the total staff than it is to obtain a high level of accuracy for every input data item. It is strongly recommended that plans for extensive data collection be deferred until steps 2 and 3 described below are implemented.

STEP 2: Assess the Quality of the Input Data Items

After the initial staffing estimates have been obtained, each of the input data items should be assessed in terms of completeness, reliability, and accuracy. The assessment of each data item will be, to some extent, a subjective process. As an example, it may be determined that the number of category 2 roadway miles in an APA equals 68 miles. If this figure is obtained from the state or state highway department based on recent data, it can be concluded that this data item is fairly "strong." On the other hand, if the average service time for handling accidents is based on a survey of three field sergeants who give individual estimates of 2.1, 2.5, and 3.2 hours, it would be clear that further effort is needed to obtain a better estimate. It is recommended that all the data items be placed into three or four groups depending on their relative quality (i.e., accuracy, reliability, etc.). Those data items in the lowest category (i.e., least accurate, least reliable, etc.) will be the initial candidates for additional refinement.

STEP 3: Investigate the Sensitivity of the Staffing Estimates to Changes in Individual Data Items

The next step is to identify which of the "soft" input data items should be refined. The basis for identifying these items is to determine which items make the biggest contribution to the overall staffing estimate. Not all input data items in PAM are equally important. For example, in an agency that places a low priority on uncommitted patrol visibility on category 3 roadways, it may not be important to have a highly accurate figure for the number of category 3 roadway miles in the APA since a change of 20 or 30 percent in the number of miles may only have a minimal impact on the final staffing estimates. In contrast, final staffing estimates tend to be fairly sensitive to changes in the value used for the shift relief factor for an agency, and changes of only 3 or 4 percent in the relief factor can produce equally-sized changes in the final staffing estimates. Sensitivity analyses should be done for each of the input data items in the lowest data quality categories to identify those items for which additional accuracy is needed.

STEP 4: Improve Accuracy of Important Data Items

The final step recommends that the input data items targeted for additional refinement be prioritized based on the results of steps 2 and 3 above. Such a list serves two purposes. First, effort can be directed toward those data items that are "soft" and, equally important, that have a significant impact on the final staffing figures. Second, limited resources can be targeted efficiently to insure that the maximum benefit in terms of the quality of the final results is obtained. As each input data item is improved, more reliable staffing figures will be generated. Clearly, this process has no natural termination point, but rather is limited by the resources and time that are available. At some point, the effort and resources required to improve the input data values will outweigh the value gained by the changes in the overall staffing estimate.

APPENDIX A: Comprehensive List of Data Requirements for Use of the PAM Model

This appendix presents a list of all of the data items that may be used in the PAM model. The list is organized by the worksheet in which each item is first used.

Worksheet 1: Operations, Workload, and Roadway Data

All of the data items in Worksheet 1 are required.

Data Item	Worksheet Identifier
Name of the APA	1.1
Shift length (hours)	1.2.1
Average number of on-duty hours on patrol per year per officer	1.2.2.1
Average number of benefit (paid) off-duty hours per year per officer	1.2.2.2
Average number of on-duty hours spent on non-patrol temporary assignments per year per officer	1.2.2.3
Average number of troopers to be supervised by each field supervisor	1.2.3
Percentage of field supervisor on-duty time spent on uncommitted patrol, reactive, and self-initiated activities	1.2.4
Type name, category 1 roadways in the APA	1.2.5.1
Patrol coverage per week (hours), category 1 roadways in the APA	1.2.5.2
Average patrol speed (MPH), category 1 roadways in the APA	1.2.5.3

Patrol interval performance objective (hours), category 1 roadways in the APA 1.2.5.4

Type name, category 2 roadways in the APA 1.2.6.1

Patrol coverage per week (hours), category 2 roadways in the APA 1.2.6.2

Average patrol speed (MPH), category 2 roadways in the APA 1.2.6.3

Patrol interval performance objective (hours), category 2 roadways in the APA 1.2.6.4

Type name, category 3 roadways in the APA 1.2.7.1

Patrol coverage per week (hours), category 3 roadways in the APA 1.2.7.2

Average patrol speed (MPH), category 3 roadways in the APA 1.2.7.3

Patrol interval performance objective (hours), category 3 roadways in the APA 1.2.7.4

Total number of days in the workload sample period 1.3.1

Total number of accidents handled by the agency during the sample period 1.3.2

Average service time (hours) per accident 1.3.3

Total number of other CFS handled by the agency during the sample period	1.3.4
Average service time (hours) per CFS	1.3.5
Number of miles, category 1 roadways in the APA	1.4.1
Number of miles, category 2 roadways in the APA	1.4.2
Number of miles, category 3 roadways in the APA	1.4.3

Worksheet 2: Administrative Time

In Worksheet 2, the user has the option of providing data item 2.1 or data items 2.2.1 and 2.2.2.

Data Item	Worksheet Identifier
Administrative time performance objective in minutes per hour per trooper	2.1
Total time (hours) spent on administrative activities during the sample period	2.2.1
Total on-duty hours on patrol during the sample period	2.2.2

Worksheet 3: Reactive Time

All data items are required for Worksheet 3 are obtained from Worksheet 1.

Worksheet 4: Proactive Time - Self-Initiated

In Worksheet 4, the user has the option of providing data item 4.1 or data items 4.2.1, 4.2.2, and 4.2.4, or data items 4.3.1 and 4.3.2.

Self-initiated performance objective time in minutes per hour per trooper	4.1
Total number of self-initiated contacts during the sample period	4.2.1
Total time (hours) spent on self-initiated contacts during the sample period	4.2.2
Number of self-initiated contacts per shift per trooper performance objective	4.2.4
Total time (hours) spent on self-initiated contacts during the sample period	4.3.1
Total on-duty hours on patrol during the sample period	4.3.2

Worksheet 5: Proactive - Uncommitted Patrol

In Worksheet 5, the user has the option of providing data items 5.2.2 and 5.2.6 or data items 5.3.2, 5.3.3, 5.3.4.

Data Item	Worksheet Identifier
Coverage per week for immediate response (hours)	5.2.2

Performance objective percentage of accidents, CFS, and self-initiated activities for which there will be at least one trooper available	5.2.6
Coverage per week for area patrol (hours)	5.3.2
Area (square miles) of the APA	5.3.3
Average response speed (MPH)	5.3.4
Average travel time performance objective (minutes)	5.3.5

Worksheet 6: Average Daily Number of On-Duty Troopers

In Worksheet 6, the user can provide data item 6.2.1 or data item 6.3.1.

Data Item	Worksheet Identifier
Percentage of time patrol units are staffed with two troopers	6.2.1
Average minimum number of on-duty troopers required per day for all patrol activities, based on agency policy	6.3.1

Worksheet 7: Special Assignments and Field Supervision

In Worksheet 7, the user has the option of using all, some, or none of the data items listed below.

Data Item	Worksheet Identifier
Name of special assignment 1	7.2.1.1

Average number of on-duty troopers on specialized assignment 1	7.2.1.2
Percentage of on-duty time spent on patrol by troopers assigned to special assignments 1	7.2.1.3
Name of special assignment 2	7.2.2.1
Average number of on-duty troopers on specialized assignment 2	7.2.2.2
Percentage of on-duty time spent on patrol by troopers assigned to special assignments 2	7.2.2.3
Name of special assignment 3	7.2.3.1
Average number of on-duty troopers on specialized assignment 3	7.2.3.2
Percentage of on-duty time spent on patrol by troopers assigned to special assignments 3	7.2.3.3

Worksheet 8: Total Staff Requirements

In Worksheet 8, the user may provide data item 8.4.

Data Item	Worksheet Identifier
Number of staff and command personnel - agency policy	8.4

Worksheet 9: Allocation of Patrol Personnel Among Several APAs

Data Item	Worksheet Identifier

Total number of additional personnel for all APAs (enter a negative value for personnel reduction)	9.1.1
Total number of current personnel	9.1.2
Number of current personnel in each APA	9.1.3
Number of personnel estimated for each APA by the PAM model	9.1.5

Supplemental Worksheet: Uncommitted Patrol Availability - Immediate Response

The supplemental worksheet for Section 5.2 is located in Appendix A in the Manual.

Data Item	Worksheet Identifier
Percent of on-duty staff on shift 1	A.2.1
Percent of on-duty staff on shift 2	A.2.2
Percent of on-duty staff on shift 3	A.2.3
Performance objective percentage of accidents, CFS, and self-initiated activities on shift 1 for which there will be at least one trooper available	A.6.1.1
Performance objective percentage of accidents, CFS, and self-initiated activities on shift 2 for which there will be at least one trooper available	A.6.2.1
Performance objective percentage of accidents, CFS, and self-initiated activities on shift 3 for which there will be at least one trooper available	A.6.3.1

Supplemental Worksheet: Uncommitted Patrol Availability - Travel Time for Line Patrol

The supplemental worksheet for Step 5.3.7 is located in Appendix B in the Manual.

Data Item	Worksheet Identifier
Coverage per week for line patrol (hours)	B.2
Total roadway miles to be patrolled in the APA	B.3
Average response speed (MPH)	B.4
Average travel time performance objective (minutes)	B.5

APPENDIX B: Glossary and Worksheet Abbreviations and Notation

Glossary

Accident - In PAM, an accident refers to a sequence of events involving one or more vehicles that produces injury, death, or property damage and requires investigative time by one or more troopers.

Administrative time - Time spent by patrol personnel on activities other than reactive, self-initiated, or uncommitted patrol. May include supervision, meals, on-duty court time, auto maintenance, training, and agency administrative duties.

Agency policy - The specification of performance objectives for use in the PAM model. (See "Performance Objective.")

Allocation - In the PAM model, allocation refers to the distribution of a specified number of troopers over several APAs.

Area - The geographic area of the APA in square miles. Large areas within the jurisdiction without roads (e.g., lakes, wilderness areas, etc.) should not be included. The area is used to determine the number of troopers needed to provide a specified average travel time to accidents and other CFS. The value used in the model may include areas outside of the jurisdiction of the agency if passage through these areas is routinely used in responding to accidents and other CFS.

Area patrol - Patrol assignment which includes responsibility for both traffic services and general police response within a specified geographic area. (See "Line Patrol.")

Autonomous patrol area (APA) - Patrol area in which one or more troopers are assigned which has the following characteristics: (1) CFS may be assigned to any of the troopers in the APA, (2) CFS are rarely dispatched to troopers assigned outside of the APA, and (3) troopers assigned to the APA rarely respond to CFS outside of the APA.

Availability - In the PAM model, one criterion for determining the number of troopers required for uncommitted patrol is based on an analysis of the number of troopers that must be "available" in order to meet two performance standards: (1)

the likelihood or probability (set by the user) that at least one trooper will be available for immediate dispatch to a CFS, and (2) that enough troopers will be available to insure that a specified average travel time (set by the user) will be met.

Average work week - The average number of paid on-duty hours per officer per week.

Backup unit - A patrol unit that is assigned or responds to a CFS to assist the primary unit.

Benefit days off - Paid time off taken by officers in addition to regular days off provided by the work schedule. Benefit time off includes vacation leave, sick leave, holidays, and compensatory time off.

CFS - CFS stands for "calls for service" (i.e., calls to the police agency which require the dispatch of one or more troopers). The PAM model uses the total time required to service CFS as the workload measure for reactive time. For agencies with full police powers, CFS include criminal activities, traffic accidents, and various other police services. Some agencies may limit their reactive time to CFS which consist primarily of traffic accidents and assistance to motorists and other agencies.

Citation - A summons or notice to appear issued by an officer for a traffic law violation.

Compensatory time off - Time off granted in lieu of monetary payment for overtime work. Compensatory time or "comp time" may be granted at different rates. A straight time rate implies that one hour of comp time is given for each hour of overtime worked. A comp time rate of time and a half implies that 1 1/2 hours of comp time is granted for each hour of overtime.

Constrained allocation - Constrained allocation refers to the distribution of a specific number of officers over several APAs with limitations on the number of officers that can be assigned to each APA. In the PAM model, constrained allocation is used for two cases: (1) when a specific number of officers are to be added to an existing allocation, the constrained allocation will determine a new allocation of the existing and new officers with the limitation or "constraint" that the revised staffing level for each APA must equal or exceed the existing level for each APA, and (2) when a specific number of officers are to be subtracted from an existing allocation, the constrained allocation will

determine a new allocation of the reduced number of officers with the limitation or constraint that the revised staffing level for each APA must not exceed the existing staffing level for each APA. (See "Unconstrained Allocation.")

Contacts - In the PAM model, contacts refers to self-initiated activities. One measure of the level of self-initiated activity is a count of the number of self-initiated contacts (i.e., the number of stops for traffic violations, warnings, and assists) per hour per shift.

Controlled-access highway - A roadway in which owners or occupants of abutting lands have no legal right of access to or from the roadway except at such points only and in such manner as may be determined by the public authority having jurisdiction over the roadway (e.g., most interstate highways).

Deployment plan - A generic term that refers to the resource allocation staffing plan for an agency. A comprehensive deployment plan may indicate the level of staff resources that are needed and how those resources should be allocated by time (e.g., by time of day and day of the week) and by geography (e.g., by APA).

Trooper - The initial rank for officers in state police departments.

Deterrence - The impact of visible patrol units on potential traffic and criminal offenders. (See "Preventive Patrol.")

Dispatching time - The time interval that begins when a call is received at the dispatching center and ends when the assignment is communicated to a trooper.

Dispatched unit - A patrol unit that is assigned to a CFS by the dispatching or telecommunication center.

Field supervisor - Field supervisor refers to agency personnel who provide on-the-road supervision of patrol troopers. Typically, field supervisors hold the rank of corporal, or sergeant.

Follow-up investigation - Investigation of an incident after the initial on-scene investigation.

Fraction - In the PAM model, a fraction refers to a number between zero (0) and one (1). A fraction can be converted to a percentage by multiplying it by 100. For example, a fraction of 0.5 is equivalent to 50% (i.e., 100 x 0.5 = 50).

Full-time - In PAM, the term "full-time" is used to refer to troopers and field supervisors who are assigned exclusively to patrol. Officers who work on non-patrol units or have permanent special assignments are not "full-time" on patrol.

Historical experience - Refers to the derivation of a value in the PAM model based on data from the past experience of an agency.

Immediate response - An agency provides an "immediate response" to a CFS when the assignment is dispatched as soon as it is received at the dispatching center and the assigned unit begins travel to the scene as soon as it receives the assignment. (See "Probability of Immediate Response.")

Interstate highway - A roadway identified by the Federal government as part of the U.S. National Interstate and Defense Highway system. Interstate highways must conform to a number of design requirements (e.g., they must be limited access roadways) and are designated by red and blue identification shield-shaped signs.

Jurisdiction - The entire area in which an officer has law enforcement powers. For sheriffs' agencies, the "jurisdiction" usually includes one state.

Line patrol - Patrol assignment for which troopers are assigned exclusively to roadway segments. (See "Area Patrol.")

Linear patrol - Same as "Line Patrol."

Model - The PAM model is a systematic procedure for representing the relationships between the staff requirements for police agencies and a number of workload, operational, and policy descriptors.

Moving patrol - Uncommitted patrol time during which a patrol vehicle is moving with the normal flow of traffic. (See "Stationary Patrol.")

Non-patrol time - In PAM, "non-patrol time" refers to on-duty time spent on special assignments.

Non-permanent assignment - A temporary special assignment. Temporary special assignments that require one or more shifts (e.g., assignment to a state fair) are usually included in the calculation of the shift relief factor for the agency. Temporary special assignments that require less

than one shift are included in the "administrative" time category. (See "Special Assignments.")

Non-supervisory work - Work done by a field supervisor that does not involve the supervision of subordinates. Non-supervisory work usually includes patrol activities that could be performed by troopers.

Obligated time - The total time required by patrol units to respond to and service CFS. Obligated time includes the travel time, on-scene time, report writing time, and follow-up investigation time expended by all patrol units that respond to a CFS. In the PAM model, total obligated time is based on the time spent by each unit, not each officer. Total obligated time serves as the workload measure to determine the number of patrol units required for reactive time activities. Total obligated time is also referred to as total service time or total reactive time.

Officers - A generic term that refers to sworn personnel in a law enforcement agency.

On-duty time - In the PAM model, on-duty time refers to the actual time that an officer appears for work. On-duty time includes both patrol time and non-patrol time. Non-patrol time includes time spent on temporary special assignments. On-duty time can be determined by assuming that an officer works every day and subtracting the number of days that an officer is off duty for both scheduled time off (i.e., regular days off) and benefit time off (i.e., vacation time, holidays, sick leave, etc.). If this method is used, paid overtime must be added to determine the total on-duty time.

One-trooper unit - A patrol unit with only one trooper assigned to it.

Patrol activity - A generic term that refers to the activities included in the four time categories used in the PAM model (i.e., reactive, self-initiated, uncommitted patrol, and administrative).

Patrol area - See "Area."

Patrol contacts - Used in the PAM model to refer to incidents included in the "self-initiated" category (e.g., an officer who issues four citations and assists two motorists during one shift would have had six contacts).

Patrol coverage - Patrol coverage is used in the PAM model to indicate the presence of agency patrol activities by roadway category. Coverage is indicated in terms of hours per week. Complete coverage of a roadway segment (i.e., 24 hours per day, seven days per week) is 168 hours per week. Some agencies may only provide partial patrol coverage on some roadways (e.g., coverage may only be provided during the day and afternoon shifts). If coverage is provided for only two shifts a day, the coverage is 112 hours per week (i.e., 2 shifts/day x 8 hours/shift x 7 days/week). The extent or intensity of patrol coverage is measured by the patrol interval. (See "Patrol Interval.")

Patrol interval - A measure of the extent or intensity of patrol coverage. The patrol interval is defined as the frequency with which a trooper will pass a given point on the roadway or the average time a stranded motorist would have to wait for a trooper to come by on uncommitted patrol. Patrol interval is determined by the number of roadway miles, the number of patrol units, the amount of uncommitted patrol time per hour per unit, and the average patrol speed.

Patrol speed - The average speed in miles per hour of a unit while on uncommitted patrol. The speed can be determined by dividing the miles driven per shift by uncommitted patrol time. The total miles should <u>not</u> include miles driven while responding to an accident or other CFS, or performing an administrative activity. Uncommitted time does not include time spent on administrative, reactive, or self-initiated activities. The time spent on uncommitted patrol should include time spent on both moving and stationary patrol.

Patrol unit - A vehicle used by one or two troopers for patrol activities. In the PAM model, the procedures used in worksheets 2 - 5 and Section 6.1 in Worksheet 6 are based on the assumption that each patrol unit has one trooper. As a result, in these worksheets, the terms "number of patrol units" and "number of troopers on patrol" are used interchangeably. (An adjustment for the use of two-trooper patrol units is presented in Worksheet 6.)

Performance objective - A target or specified performance standard that is set either by policy or by historical experience. In the PAM model, performance objectives may be set for (1) the number of minutes per hour per trooper spent on administrative activities, (2) the number of minutes per hour per trooper spent on self-initiated activities, (3) the number of self-initiated contacts per shift per trooper, (4) the average patrol interval, (5) the percentage of accidents

and other CFS for which a trooper can be dispatched immediately, (6) the average travel time to accidents and other CFS, (7) the percentage of two-trooper units, (8) the average number of troopers per field supervisor, and (9) the number of staff and command personnel required.

Permanent assignment - An assignment that will continue for an indefinite period of time. In PAM, the adjustment for the number of officers required for patrol when some officers are on permanent special assignment is covered in Worksheet 7.

Preventive patrol - Visible uncommitted patrol designed to prevent or limit unlawful activity. (See "Deterrence.")

Primary highway - A U.S. or state-numbered route, or other major highway designated by authorities as part of a major system of roadways within their jurisdiction.

Primary unit - Patrol unit that is assigned to or initiates a patrol activity and has responsibility for investigating and reporting the activity.

Proactive time - Proactive time refers to time spent by a trooper on self-initiated activities and uncommitted patrol; it includes the time spent performing the activity (e.g., issuing a citation) and the time spent on uncommitted patrol looking for the activity (e.g., for traffic violators).

Probability of immediate response - The probability that when the next CFS arrives, at least one trooper will be free or available for assignment to the call.

Queuing theory - A branch of mathematics that uses statistics and probability to describe the operating characteristics of queues (i.e., waiting lines). The receiving and assigning of CFS at a police dispatching center can be viewed as a waiting line operation in which CFS represent customers who will have to wait in line (i.e., stacked) if all of the servers (i.e., patrol units) are busy. The determination of the "probability of immediate response" in the PAM model is based on formulas derived from queuing theory.

Reactive time - The total time required by all patrol units to respond to and handle a CFS. (See "Obligated Time.")

Reallocation - In PAM, the term "reallocation" is used to

identify or distinguish a revised allocation of a specific number of officers over several APAs from the original or initial distribution of the officers.

Regular duty - The usual or permanent assignment for a trooper or field supervisor. Regular duty may consist of patrol duty, special assignment, or a combination of both. An officer is not on regular duty while on temporary assignment.

Response speed - The average speed in miles per hour of a patrol unit responding to an accident or other CFS.

Resource allocation - In PAM, resource allocation refers to the determination of the number and allocation of law enforcement personnel whose primary mission is the delivery of police traffic services.

Roadway - A generic term used in PAM to refer to any type of highway or street patrolled by a state-wide law enforcement agency (e.g., interstate highways, primary highways, secondary highways, municipal streets, etc.)

Sample period - In PAM, the sample period refers to the time period for which data is collected. It is not necessary that all of the input data used in the PAM model be obtained from the same "sample period."

Secondary highway - Any non-arterial or rural roadway.

Self-initiated activities - Activities carried out by patrol officers that are not assigned by a dispatcher. Examples include most traffic enforcement and motorist assists.

Self-initiated contact - See "Contacts."

Service time - The total time expended by a patrol unit to handle an accident, CFS, or self-initiated activity. Service time includes travel time (for dispatched calls), on-scene time, report writing time, and follow-up investigation time expended by all units that provide service. Service time does not include dispatching time. Service time spent on dispatched calls is used to determine the total obligated time for an agency. (See "Obligated Time.")

Service-on-demand - A term used to characterize CFS in order to distinguish them from self-initiated activities.

Shift - An officer's regular on-duty period; sometimes called a tour or watch.

Shift length - The length in hours of each tour, watch, or shift.

Shift relief factor - The shift relief factor indicates the average number of personnel needed to provide one on-duty officer for one shift every day. Shift relief factors for agencies with eight-hour shift lengths are usually between 1.6 and 1.9. The shift relief factor is multiplied by the average number of on-duty personnel required per day to determine the total staff size. Shift relief factors depend on the shift length, average work week, benefit time off policies of the agency, and the amount of on-duty, non-patrol time per officer.

Special assignments - Additional assignments given to patrol personnel (e.g., accident reconstruction and hazardous materials). Permanent special assignments are handled in Worksheet 7 of the Manual. Time spent on temporary special assignments that last for more than one shift are not included in any of the four patrol time categories used in the PAM model, but are accounted for in the determination of the shift relief factor. Time spent on temporary special assignments that require less than one shift are included in administrative time.

Staff - The PAM model uses the term "staff" to refer to the total number of sworn personnel (both on- and off-duty) that are required to provide a specified number of on-duty officers per day.

Staff and command personnel - Those personnel assigned to an APA or several APAs who provide support services (e.g., training, range, or desk officers) and the command staff above the rank of field supervisor.

Stationary patrol - Uncommitted patrol time in which the patrol vehicle is not in motion. Examples include running stationary mode radar and observing an intersection or high accident location for traffic violators.

Temporary assignment - See "Non-Permanent Assignment."

Tour - See "Shift."

Travel time - The time interval that begins when a patrol unit receives a CFS assignment from a dispatcher and ends when the unit arrives on scene. Travel time does not include dispatching time.

Two-trooper unit - A patrol unit with two officers assigned to it.

Uncommitted patrol - Time spent by patrol personnel on activities other than reactive, self-initiated, or administrative. Uncommitted patrol time is used to provide agency visibility for the deterrence of traffic violators and agency availability for reactive and self-initiated activities.

Uncommitted time - See "Uncommitted Patrol Time."

Unconstrained allocation - Unconstrained allocation refers to the distribution of a specific number of officers over several APAs with no limitations on the number of officers that can be assigned to each APA. (See "Constrained Allocation.")

Uniform staffing - Uniform staffing by shift or APA refers to an allocation in which the same number of officers are assigned to each shift, day of the week, or APA.

Visibility - One purpose of uncommitted patrol is to promote the general deterrence of traffic and criminal violators by maintaining a high level of trooper visibility.

Watch - See "Shift."

Work activity - See "Patrol Activity."

Workload - In the PAM model, the term workload refers to the total obligated time generated by all accidents and other CFS, and the total time required to provide a user- specified level of self-initiated activities.

Worksheet Abbreviations and Notation

APA - Autonomous patrol area.

AWW - Average work week.

CAD - Computer-aided dispatching.

CFS - Calls for service.

H_b - Average number of benefit (paid) hours off per year per officer.

H_{np} - Average number of on-duty hours on patrol per year officer per year.

H_t - Total hours required to cover one shift position for one year.

H_{ta} - Average number of on-duty hours on temporary assignments (non-patrol) per officer per year.

H_y - Average number of paid hours of work per year per officer.

f_{si} - Fraction of on-duty time spent on non-patrol activities by troopers assigned to special unit i.

H_i - Hours of coverage on roadway segment i.

K - Number used in Section 5.3 to determine the number of troopers required to meet the travel time performance objective for area patrol. Based on the average response speed and the travel time objective in minutes.

K_f - Factor used in WorkSheet 7 to adjust the daily number of on-duty troopers. Based on the average number of troopers that report to each field supervisor and the percentage of time supervisors spend on patrol work.

K_s - Number used in Appendix A in the Manual to

determine which table to use to estimate the number of troopers required for immediate response. Based on m_a and m_s.

M_i - Length (miles) of roadway segment i.

m_a - The average number of minutes per hour per trooper spent on administrative time.

MPH - Miles per hour.

m_r - The average number of minutes per hour per trooper spent on reactive activities (i.e., dispatched accidents and other CFS).

m_s - The average number of minutes per hour per trooper spent on self-initiated activities (e.g., traffic citations, traffic warnings, and motorist assists).

N - The average number of on-duty troopers required per day unadjusted for two-trooper units, special assignments, or field supervision.

N_{ao} - Adjusted average daily number of on-duty troopers.

N_{asi} - Adjusted daily number of on-duty troopers assigned to special assignment i.

N_{ft} - The average number of full-time, on-duty troopers required per day.

N_h - The total number of personnel required for staff and command, both on and off-duty.

N_{min} - The average minimum number of on-duty patrol troopers required per day.

N_o - The average total number of on-duty troopers per day.

N_{os} - The average number of on-duty field supervisors per day.

N_{ot} - The average number of on-duty troopers per day.

N_p - The average number of on-duty troopers required per day to meet the uncommitted patrol time requirement.

N_{pi} - The average number of on-duty troopers required on shift i to meet the uncommitted patrol time requirement.

N_r - The average number of on-duty troopers required per day to meet the reactive time (service-on-demand) requirement.

N_{ri} - The average number of on-duty troopers required on shift i to meet the reactive time (service-on-demand) requirement.

N_{rs} - The average number of on-duty troopers required per shift to meet the reactive time (service-on-demand) requirement.

N_s - The total number of field supervisors, both on and off-duty.

N_{si} - The number of on-duty troopers assigned to special unit i.

N_t - The total number of troopers, both on and off-duty.

N_{tot} - The total staff requirement.

PAM - Police Allocation Manual.

PIR% - The agency-specified performance objective for the percent of accidents, other CFS, and self-initiated activities for which at least one trooper will be available.

PIRi - The agency-specified performance objective for the percent of accidents, other CFS, and self-initiated activities on shift i for which at least one trooper will be available.

SRF - Shift relief factor.

TA - The total staff to be added (or subtracted) for the allocation.

TC - The total current staff.

TE - The total staff requirement based on PAM estimates.

TN - Total overstaffing (or understaffing) based on current staff levels and PAM staff estimates for each APA.

APPENDIX C: Example Using PAM Worksheets 1 - 9 To Determine Staffing Requirements and Allocation

Introduction

This appendix illustrates the use of worksheets 1-8 to determine staffing levels for one APA and Worksheet 9 to allocate staff among three shifts. The data used for this example are based on information obtained from the field test agencies during Phase III of the PAM project.

The remainder of this appendix is divided into two parts. The first presents observations about the example agency and the particular options used in each worksheet. Comparisons between the data values used or calculated for the example and the field test results (shown in Table 1 in the Guide) are also discussed. The second part consists of the completed worksheets.

Observations

In the discussion below, references to specific values in the worksheets are made by identifying the corresponding worksheet step numbers in parentheses.

Worksheet 1: Operations, Workload, and Roadway Data

The example APA covers the entire barraks area for a state police department that has police patrol responsibilities over all the unincorporated areas for a large section of a state state that also contains a city of approximately 300,000. The agency handles a large number of accidents (1.3.2) and other calls-for-service (CFS) (1.3.4) each year. The jurisdiction contains 152 miles of primary highways (1.4.1), 775 miles of rural highways (1.4.2), and 488 miles of residential streets (1.4.3). The agency provides full coverage (i.e., 168 hours per week) ((1.2.5.2), (1.2.6.2), and (1.2.7.2)) over all roadways. A patrol interval of 8 hours is used for primary highways (1.2.5.4) while rural highways and residential streets are patrolled with a target interval of 24 hours, (1.2.6.4) and (1.2.7.4).

Worksheet 2: Administrative Time

The agency uses historical data in Section 2.2 to determine that the administrative time per hour per trooper is 10.8 minutes (2.2.3). The field test average for Section 2.2 was 12.07 minutes.

Worksheet 3: Reactive Time

The total obligated time per day for the agency is 29.51 hours (3.3.1) which consists of 9.39 hours for accidents (3.1.5) and 20.12 hours for all other CFS (3.2.5). Based on an 8-hour shift, this level of workload requires 3.69 on-duty troopers per day (3.3.3). The average service time for accidents is 2.40 hours (3.1.2) which is slightly higher than the field test average of 1.88 hours. The average time of 0.85 hours for all other CFS (3.2.2) is very close to the field test average of 0.87 hours.

Worksheet 4: Proactive Time - Self-Initiated

The agency determines the self-initiated time based on the historical experience of the agency and policy in Section 4.2. The average of 9.75 minutes per hour per trooper (4.2.7) is most equal to the field test average of 9.80 minutes for the same section. (Note: the field test average of 9.80 was based on only one field test application. The average for Section 4.3 (9 applications based on historical data) was 7.49 minutes per hour per trooper.)

Worksheet 5: Proactive Time - Uncommitted Patrol

In Section 5.1, the agency calculates a requirement of 7.94 on-duty troopers per day (5.1.5) to provide the desired level of patrol visibility. The 7.94 troopers consist of 1.33 troopers (5.1.2.6) for primary highways to meet the 8-hour patrol interval objective (5.1.2.5), and 3.23 troopers (5.1.3.6) for rural highways and 3.39 on-duty troopers for residential streets (5.1.4.6), both to meet a 24-hour patrol interval, (5.1.3.5) and (5.1.4.5).

For patrol availability, the agency examines two options: the immediate response option in Section 5.2 and the travel time for area patrol option in Section 5.3. Based on an immediate response objective of 95% (5.2.6), the agency determines that 3.4 on-duty troopers (5.2.7) are needed per shift to insure that at least one trooper will be immediately available for 95% of the accidents, other CFS, and self-initiated activities. The daily requirement for 3 shifts is 10.2 troopers (5.2.8).

The assumptions required for the use of Section 5.2 are that m_a equals 9 minutes, m_s equals 15 minutes, and that staffing is equal over all shifts. These values for m_a and m_s produce an adjustment factor (K_f) value of 0.25 which is used to produce the values in Table 3-1. For the example agency, the actual values of m_s = 10.8 minutes (2.3), m_s = 9.75 minutes (4.4) which yields an adjustment factor value of 0.247. This result plus the fact that the agency uses uniform staffing over the 3 shifts indicates that there is no need to use the supplement worksheet in Appendix A (not shown) in place of Section 5.2.

In Section 5.3, the required on-duty staffing for area patrol is determined. The agency provides around-the-clock coverage over the entire area of the jurisdiction (520 square miles, (5.3.3)). Based on an average response speed of 40 miles per hour (5.3.4) and a target travel time of 15 minutes (5.3.5), the number of troopers required for area patrol is 6.93 (5.3.6).

Since the agency has no patrol units assigned exclusively to designated roadway segments (i.e., line patrol), the supplemental worksheet in Appendix B (not shown) is not used.

To determine the number of troopers for availability, the agency compares the results of sections 5.2 and 5.3 and selects the larger value (i.e., 10.2 on-duty troopers for immediate response, Section 5.2). The last step in Worksheet 5 (5.5) is used to determine the number of on-duty troopers for uncommitted patrol. This is done by comparing the number of on-duty troopers needed for "visibility" (i.e., 7.94 troopers in Step 5.1.5) with the number of troopers needed for "availability" (i.e., 10.2

troopers in Step 5.4) and selecting the larger value. Hence, a value of 10.2 troopers is entered in Step 5.5.

Worksheet 6: Average Daily Number of On-Duty Troopers

The agency uses Section 6.1 to determine that 21.12 on-duty troopers (6.1.5) will be needed each day. Since no patrol units are staffed with two troopers and the agency has no overall minimum staffing requirements for the jurisdiction, the number of troopers is unchanged for sections 6.2 and 6.3.

Worksheet 7: Special Assignment and Field Supervision

Worksheet 7 is used to adjust the number of troopers for patrol work performed by field supervisors and troopers on special assignment. For the example, each field supervisor is responsible for an average of 10 troopers and spends approximately 60% of his/her time on patrol (i.e., non-supervisory) activities. In Section 7.1, the agency determines that the adjusted number of on-duty, full-time troopers is 19.93 (7.1.6).

The agency uses an average of 3 troopers (7.2.1.2) on-duty each day for crime prevention activities. Each trooper assigned to the unit spends only about 5% of his/her time on patrol (7.2.1.3). The adjusted number of on-duty troopers for crime prevention is 2.69 (7.2.1.6).

The total adjusted daily number of on-duty troopers equals 22.62 (7.2.4). The number of on-duty, full-time troopers can be obtained by subtracting all the on-duty special assignment staff (i.e., 3 troopers) from the total adjusted number of troopers found in Step 7.2.4; that is, the number of on-duty, full-time troopers equal 19.62.

The total number of on-duty field supervisors required per day is 2.26 (7.3.1). This value is obtained by dividing the adjusted number of on-duty troopers (7.2.4) by the average number of troopers that report to each supervisor (7.1.1).

Worksheet 8: Total Staff Requirement

Since the agency has an average work week of 40 hours (8.23), the average number of paid hours of work per year per trooper is 2,085.71 (8.2.4). When non-patrol time for benefit time off (8.2.5) and temporary special assignments (8.2.6) are removed, the average number of patrol hours per year per trooper equals 1,795.21 (8.2.7). The shift relief factor for the agency is

1.627 (8.2.8). Multiplying the on-duty trooper and field supervisor estimates by the shift relief factor yields the total staff requirements (i.e., 36.79 troopers (8.3.1) and 3.68 field supervisors (8.3.2)).

The agency uses Section 8.4 to specify a total of 4 staff and command personnel. The total staff requirement of 44.46 officers for the APA is recorded in Section 8.5.

Worksheet 9: Allocation of Patrol Personnel Among Several shifts

Only Table 4-1 from Worksheet 9 is shown below to illustrate the allocation procedure. The allocation example is based on 3 shifts. The current staffing levels for each shift are shown in column 1. The sum of column 1 indicates that the total current staffing (**TC**) is 39 troopers. The PAM staffing estimates for each shift are shown in column 2. (The derivations of these estimates are not shown.) The sum of column 2 indicates that the total staff estimate (**TE**) for the 3 shifts from the PAM model is 45 troopers (the value obtained when the staffing estimate for each shift is rounded to a whole number and the results are added). Comparison of the columns 1 and 2 indicates that shifts 2 and 3 are understaffed. For the example allocation, 6 additional troopers (**TA**) are to be added to the current staffing total of 39.

The values for the unconstrained allocation of the 45 troopers (i.e., 45 + 12) are shown in column 3. (See Step 9.1.7 in Worksheet 9 for the formula used to determine the values in column 3.)

Columns 4 - 8 are used to determine the constrained allocation of the 45 troopers. The difference between the values in columns 1 and 3 for each shift are shown in column 4. The difference indicates the amount of over or understaffing for each shift. (Only shift 1 has a positive value which indicates it is overstaffed.) Since the total staff is to be increased (i.e., **TA** > 0), the procedures described in Step 9.2.3 are used to determine the values in column 5. (For each shift, if the value in column is negative, it is copied in column 5. If the value in column 4 is positive, a zero is entered in column 5.) Step 9.2.3.3 is used to calculate how the 6 new troopers will be distributed over the 3 shifts (column 6). For the constrained allocation procedure, additional staff is only added to shifts that are understaffed (i.e., shifts that have negative values in column 5). The values in column 6 are rounded to whole numbers and entered column 7. (The sum of the values in column 7 must equal the number of staff to be added.) The final value for each shift for the constrained allocation, shown in column 8, is obtained by

adding the current staff (column 1) to the staff to be added (column 7). Note that even though troopers are only added to shifts 2 and 3, Shift 1 remains overstaffed.

WORKSHEET 1: Operations, Workload, and Roadway Data

Objective: Identify data items to be used for determining the number of patrol personnel within an APA.

Method: Data is identified as either operations, workload, or roadway.

1.1 Autonomous Patrol Area Name . . **Detailed Example** (1.1)

1.2 Operations Data for the APA

1.2.1 Shift length (hours) **8.0** (1.2.1)

1.2.2 Average number of on-duty hours on patrol per year per officer

1.2.2.1 Average work week (average number of paid hours per week per officer) **40.0** (1.2.2.1)

1.2.2.2 Average number of benefit (paid) off-duty hours per year per officer **242.2** (1.2.2.2)

1.2.2.3 Average number of on-duty hours spent on non-patrol temporary assignments per year per officer **48.3** (1.2.2.3)

1.2.3 Average number of troopers to be supervised by each field supervisor **10.0** (1.2.3)

1.2.4 Percentage of field supervisor on-duty time spent on uncommitted patrol, reactive, and self-initiated activities **60.0** (1.2.4)

1.2.5 Patrol operations - roadway category 1

1.2.5.1 Category 1 roadway type . . **Primary Highways** (1.2.5.1)

1.2.5.2 Coverage per week (hours), (maximum value = 168) . . . **168.0** (1.2.5.2)

1.2.5.3 Average uncommitted patrol speed (MPH) **43.0** (1.2.5.3)

1.2.5.4 Patrol interval performance objective (hours) **8.0** (1.2.5.4)

1.2.6 Patrol operations - roadway category 2

1.2.6.1 Category 2 roadway type . . . **Rural Highways** (1.2.6.1)

1.2.6.2 Coverage per week (hours), (maximum value = 168) . . . **168.0** (1.2.6.2)

1.2.6.3 Average uncommitted patrol speed (MPH) **30.0** (1.2.6.3)

1.2.6.4 Patrol interval performance objective (hours) **24.0** (1.2.6.4)

1.2.7 Patrol operations - roadway category 3

1.2.7.1 Category 3 roadway type . . . **Residential Streets** (1.2.7.1)

1.2.7.2 Coverege per week (hours), (maximum value = 168). . . **168.0** (1.2.7.2)

1.2.7.3	Average uncommitted patrol speed (MPH)	**18.0** (1.2.7.3)
1.2.7.4	Patrol interval performance objective (hours)	**24.0** (1.2.7.4)

1.3 Workload Data for the APA

1.3.1	Total number of days in the sample period	**365** (1.3.1)
1.3.2	Total number of accidents handled by the agency during the sample period	**1,428** (1.3.2)
1.3.3	Average service time (hours) per accident	**2.4** (1.3.3)
1.3.4	Total number of other CFS handled by the agency during the sample period	**8,639** (1.3.4)
1.3.5	Average service time (hours) per other CFS	**0.85** (1.3.5)

1.4 Roadway Data for the APA

1.4.1 Roadway category 1 (miles)	**152.0**	(1.4.1)
1.4.2 Roadway category 2 (miles)	**775.0**	(1.4.2)
1.4.3 Roadway category 3 (miles)	**488.0**	(1.4.3)

WORKSHEET 2: Administrative Time

Objective: Determine the average number of minutes per hour per trooper to be spent on administrative activities within the APA (m_a).

Method: Based either on policy decision or historical experience.

OPTION: Complete Section 2.1 or Section 2.2.

2.1 Average Number of Minutes Per Hour Per Trooper - Policy Decision

Select administrative time performance objective in minutes per hour per trooper . . . . . (2.1)

Continue with Section 2.3.

OR

2.2 Average Number of Minutes Per Hour Per Trooper - Historical Experience

2.2.1 Total time (hours) spent on administrative activities within the APA during the sample period . . **9,172.0** (2.2.1)

2.2.2 Total on-duty hours on patrol within the APA during the **50,956.00**

sample period . . . .))))))))))))-
(2.2.2)

2.2.3 Fraction of time spent on administrative activities, divide: (2.2.1) ÷ (2.2.2) . . . .

+))))))))))))),
* 0.18 *
.))))))))))))-
(2.2.3)

2.2.4 Average number of minutes per hour per trooper, multiply: (2.2.3) x 60 . . . .

+))))))))))))),
* 10.8 *
.))))))))))))-
(2.2.4)

4444444444444444444444444444444444444444444444444444444444444444

2.3 Administrative Time

Minutes per hour per trooper, select either (2.1) or (2.2.4) . . . . . (note: $0 \le \mathbf{m_a} < 60$)

6444444444447
5 **10.8** 5 ($\mathbf{m_a}$)
9444444444448
(2.3)

4444444444444444444444444444444444444444444444444444444444444444

WORKSHEET 3: Reactive Time

Objective: Determine the number of troopers required to handle accidents and other CFS within an APA (N_r).

Method: Based on the total time required to handle all accidents and other CFS, and the shift length.

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3.1 Daily Service Time Requirement for Accidents

3.1.1 Total number of accidents within the APA during the sample period, use (1.3.2) **1,428** (3.1.1)

3.1.2 Average service time (hours) for each accident, use (1.3.3) . . **2.40** (3.1.2)

3.1.3 Total obligated time for accidents within the APA during the sample period, multiply: (3.1.1) x (3.1.2) (or enter directly from CAD system) . . . **3,427.2** (3.1.3)

3.1.4 Total number of days in the sample period, use (1.3.1) **365** (3.1.4)

3.1.5 Average workload per day for accidents (hours), divide: (3.1.3) ÷ (3.1.4) **9.39** (3.1.5)

3.2 Daily Service Time Requirement for Other CFS

3.2.1 Total number of other CFS within the APA during the sample period, use (1.3.4) **8,639** (3.2.1)

3.2.2 Average service time (hours) for each CFS, use (1.3.5) **0.85** (3.2.2)

3.2.3 Total obligated time for other CFS within the APA during the sample period, multiply: (3.2.1) x (3.2.2) . . . (or enter directly from CAD system) **7,343.2** (3.2.3)

3.2.4 Total number of days in the sample period, use (1.3.1) **365** (3.2.4)

3.2.5 Average workload per day for other CFS (hours), divide: (3.2.3) ÷ (3.2.4) **20.12** (3.2.5)

3.3 Total Number of Troopers Required per Day for Reactive Time

3.3.1 Total average workload per day within the APA (hours), add: (3.1.5) + (3.2.5) **29.51** (3.3.1)

3.3.2 Shift length (hours), use (1.2.1) **8.0** (3.3.2)

3.3.3 Average number of on-duty troopers required per day

within the APA to meet the average daily workload, divide: (3.3.1) ÷ (3.3.2) . . . . .

$$\frac{\text{(3.3.1)}}{\text{(3.3.2)}} = \frac{\text{5}}{\text{3.69}} = \text{5 } (N_r)$$

(3.3.3)

WORKSHEET 4: Proactive Time - Self-initiated

Objective: Determine the average number of minutes per hour per trooper to be spent on self-initiated activities within the APA (m_s).

Method: Based either on policy decision or historical experience within the APA.

OPTION: Complete Section 4.1 or Section 4.2 or Section 4.3.

4.1 Average Number of Minutes Per Hour Per Trooper - Policy Decision (Direct)

Select self-initiated performance objective for the APA, minutes per hour per trooper . . . . . m_s = (4.1)

Continue with Section 4.4

OR

4.2 Average Number of Minutes Per Hour Per Trooper - Policy Decision (Indirect)

4.2.1 Total number of self-initiated contacts within the APA during the sample period **27,577** (4.2.1)

4.2.2 Total time (hours) spent on self-initiated contacts within the APA by all troopers on patrol during the sample period . **7,170.0** (4.2.2)

4.2.3 Average time (hours) per self-initiated contact within the APA during the sample period, divide: (4.2.2) ÷ (4.2.1) **0.26** (4.2.3)

4.2.4 Select number of self-initiated contacts per shift per trooper performance objective **5.0** (4.2.4)

4.2.5 Shift length (hours), use (1.2.1) **8.0** (4.2.5)

4.2.6 Number of self-initiated contacts per hour per trooper, divide: (4.2.4) ÷ (4.2.5) **0.63** (4.2.6)

4.2.7 Self-initiated performance objective for the APA in minutes per hour per trooper, multiply: 60 x (4.2.3) x (4.2.6) **9.75** (4.2.7)

Continue with Section 4.4

OR

4.3 Average Number of Minutes Per Hour Per Trooper -

Historical Experience

4.3.1 Total time (hours) spent on self-initiated contacts within the APA by all troopers on patrol during the sample period, (same as (4.2.2)) . . . . . (4.3.1)

4.3.2 Total on-duty hours by troopers on patrol within the APA during the sample period, (same as (2.2.2)) . . . . . (4.3.2)

4.3.3 Fraction of time spent on self-initiated activities within the APA during the sample period, divide: (4.3.1) ÷ (4.3.2) . . . . . (4.3.3)

4.3.4 Average number of minutes per hour per trooper to be spent on self-initiated activities within the APA, multiply: 60 x (4.3.3) . . . (4.3.4)

4.4 Proactive Time (Self-initiated)

Minutes per hour per trooper, select either (4.1) or (4.2.7) or (4.3.4) . . . (4.4)
(note: $0 \leq m_s < 60$)

9.75 (m_s)

WORKSHEET 5: Proactive Time - Uncommitted Patrol

Objective: Determine the number of troopers required within the APA to provide an adequate level of visibility and availability.

Method: Based on: (1) the patrol interval, and (2) the probability of immediate response to accidents and other CFS or the average travel time to accidents and other CFS.

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5.1 Uncommitted Patrol Visibility

5.1.1 Shift length (hours), use (1.2.1) **8.0** (5.1.1)

5.1.2 Number of troopers needed per day for uncommitted patrol on category 1 roadways in the APA

5.1.2.1 Category 1 roadway type, use (1.2.5.1) . . **Primary Highways** (5.1.2.1)

5.1.2.2 Miles of roadway, use (1.4.1) **152.0** (5.1.2.2)

5.1.2.3 Hours of coverage per week, use (1.2.5.2) **168.0** (5.1.2.3)

5.1.2.4 Average patrol speed **43.0**

(MPH), use (1.2.5.3) . . . (5.1.2.4)

5.1.2.5 Performance objective patrol interval (hours), use (1.2.5.4) **8.0** (5.1.2.5)

5.1.2.6 Number of troopers required per day to meet the patrol interval performance objective for category 1 roadways in the APA, use the formula below . . . **1.33** (5.1.2.6)

$$\text{Number of Troopers (5.1.2.6)} = \frac{\text{Roadway Miles (5.1.2.2)} \times \text{Hours of Coverage Per Week (5.1.2.3)}}{7 \times \text{Average Patrol Speed (5.1.2.4)} \times \text{Shift Length (5.1.1)} \times \text{Perf. Obj. Patrol Interval (5.1.2.5)}}$$

5.1.3 Number of troopers needed per day for uncommitted patrol on category 2 roadways in the APA

5.1.3.1 Category 2 roadway type, use (1.2.6.1) . . **Rural Highways** (5.1.3.1)

5.1.3.2 Miles of roadway, use (1.4.2) **775.0** (5.1.3.2)

5.1.3.3 Hours of coverage per week, use (1.2.6.2) **168.0** (5.1.3.3)

```
                                                  +)))))))))))),
5.1.3.4 Average patrol speed                      *    30.0    *
        (MPH), use (1.2.6.3)  . . .               .)))))))))))-
                                                    (5.1.3.4)

5.1.3.5 Performance objective                     +)))))))))))),
        patrol interval (hours),                  *    24.0    *
        use (1.2.6.4) . . . . . . .               .)))))))))))-
                                                    (5.1.3.5)

5.1.3.6 Number of troopers required
        per day to meet the patrol
        interval performance
        objective for category 2                  +)))))))))))),
        roadways in the APA,                      *    3.23    *
        use the formula below . . .               .)))))))))))-
                                                    (5.1.3.6)

                    Roadway              Hours of Coverage
                     Miles        x         Per Week
Number of           (5.1.3.2)              (5.1.3.3)
Troopers     =  ))))))))))))))))))))))))))))))))))))))))))))))))))))))))))))
(5.1.3.6)                 Average       Shift       Perf. Obj.
                 7   x    Patrol    x   Length    x   Patrol
                          Speed        (5.1.1)       Interval
                        (5.1.3.4)                   (5.1.3.5)
```

```
5.1.4 Number of troopers needed per day
      for uncommitted patrol on category
      3 roadways in the APA

5.1.4.1 Category 3          +))))))))))))))))))))))),
        roadway type,       *  Residential Streets *
        use (1.2.7.1) . . .))))))))))))))))))))))))-
                                   (5.1.4.1)
                                                  +)))))))))))),
5.1.4.2 Miles of roadway,                         *   488.0    *
        use (1.4.3) . . . . . . . .               .)))))))))))-
                                                    (5.1.4.2)

                                                  +)))))))))))),
5.1.4.3 Hours of coverage per                     *   168.0    *
        week, use (1.2.7.2) . . . .               .)))))))))))-
                                                    (5.1.4.3)

                                                  +)))))))))))),
5.1.4.4 Average patrol speed                      *    18.0    *
```

(MPH), use (1.2.7.3) . . . (5.1.4.4)

5.1.4.5 Performance objective patrol interval (hours), use (1.2.7.4) . . . **24.0** (5.1.4.5)

5.1.4.6 Number of troopers required per day to meet the patrol interval performance objective for category 3 roadways in the APA, within the APA, use use the formula below . . . **3.39** (5.1.4.6)

$$\text{Number of Troopers (5.1.4.6)} = \frac{\text{Roadway Miles (5.1.4.2)} \times \text{Hours of Coverage Per Week (5.1.4.3)}}{7 \times \text{Average Patrol Speed (5.1.4.4)} \times \text{Shift Length (5.1.1)} \times \text{Perf. Obj. Patrol Interval (5.1.4.5)}}$$

5.1.5 Total number of troopers required per day to meet patrol interval performance objective within the APA, add: (5.1.2.6) + (5.1.3.6) + (5.1.4.6) . . **7.94** (5.1.5)

OPTION: Complete Section 5.2 <u>or</u> the Supplemental Worksheet in Appendix A <u>or</u> Section 5.3.

5.2 Uncommitted Patrol Availability - Immediate Response

5.2.1 Shift length (hours), use (1.2.1)	**8.0** (5.2.1)
5.2.2 Coverage per week (hours), (maximum value = 168)	**168.0** (5.2.2)
5.2.3 Calculate the effective number of shifts per day based on the formula below	**3.0** (5.2.3)

$$\text{Effective Number of Shifts Per Day (5.2.3)} = \frac{\text{Coverage Per Week (hours) (5.2.2)}}{7 \times \text{Shift Length (hours) (5.2.1)}}$$

5.2.4 Average daily number of on-duty troopers for reactive time, use (3.3.3)	**3.69** (N_r) (5.2.4)
5.2.5 Average daily number of on-duty troopers per shift (N_{rs}), divide: (5.2.4) ÷ (5.2.3)	**1.23** (N_{rs}) (5.2.5)
5.2.6 Performance objective, percentage of accidents, CFS, and self-initiated activities, immediate response (a number between 50 and 99)	**95.0** (**PIR%**) (5.2.6)
5.2.7 Number of troopers required per shift, use (5.2.5), (5.2.6), and Table 3-1	**3.40** (5.2.7)
5.2.8 Total number of uncommitted patrol troopers required per day within the APA to provide immediate response to the performance objective percentage of accidents and CFS, either multiply: (5.2.3) x (5.2.7) or	**10.2**

enter value from Step (A.7) . . . .)))))))))))-
(5.2.8)

Continue with Section 5.4.

OR

5.3 Uncommitted Patrol Availability - Travel Time for Area Patrol (Steps 5.3.1 - 5.3.6) and/or Line Patrol (Step 5.3.7)

5.3.1	Shift length (hours), use (1.2.1)	**8.0** (5.3.1)
5.3.2	Coverage per week (hours) (maximum value = 168)	**168.0** (5.3.2)
5.3.3	Area (square miles) of the APA	**520.0** (5.3.3)
5.3.4	Average response speed (MPH) (equal to or greater than average patrol speed)	**40.0** (5.3.4)
5.3.5	Average travel time performance objective (minutes)	**15.0** (5.3.5)
5.3.6	Number of troopers required within the APA to meet the average travel time performance objective for area patrol	
5.3.6.1	Calculate **K** based on formula below	**0.067** *(**K**) (5.3.6.1)

$$K = \frac{40}{\text{Speed (MPH)} \times \text{Time (min)}}$$

(5.3.4) (5.3.5)

5.3.6.2 Calculate **K** x **K**, multiply (5.3.6.1) x (5.3.6.1) . . . | **0.0044** | (K^2) (5.3.6.2)

5.3.6.3 Number of troopers required for area patrol, use the formula below . . . | **6.93** | (5.3.6.3)

$$\text{No. of On-Duty Troopers, Area Patrol (5.3.6.3)} = \frac{K^2\ (5.3.6.2) \times \text{Area}\ (5.3.3) \times \text{Coverage Per Week (Hours)}\ (5.3.2)}{7 \times \text{Shift Length (hours)}\ (5.3.1)}$$

5.3.7 Number of troopers required within the APA for line patrol, enter zero or the value from Step (B.6) . . . . . | **0.0** | (5.3.7)

5.3.8 Total number of troopers required within the APA for area and line patrol, add: (5.3.6.3) + (5.3.7) . . . . . | **6.93** | (5.3.8)

5.4 Uncommitted Patrol Availability

Total troopers required within

the APA, select either (5.2.8) <u>or</u> (5.3.8) . . . .)))))))))))- * **10.20** *
(5.4)

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5.5 Total Number of Troopers Required for Uncommitted Patrol

Average number of troopers ($\mathbf{N_p}$) required per day for uncommitted patrol within the APA, select the <u>larger</u> of (5.1.5) and (5.4) . . . . 6444444444447 5 **10.20** 5 ($\mathbf{N_p}$) 9444444444448
(5.5)

444444444444444444444444444444444444444444444444444444444444

WORKSHEET 6: Average Daily Number of On-Duty Troopers

Objective: Determine the average total number of troopers required per day within the APA.

Method: Combine the total number of troopers required for reactive (N_r) and patrol activities (N_p) with the per trooper time requirements for self-initiated (m_s) and administrative (m_a) activities. Adjust the required number of troopers based on the percentage of two-trooper patrols and, if applicable, minimum daily staffing levels.

6.1 Number of On-Duty Troopers per Day - All One-Trooper Patrols

6.1.1 Administrative time - minutes per hour per trooper, use (2.3)	**10.80**	(m_a) (6.1.1)
6.1.2 Average number of troopers required per day to meet reactive time workload, use (3.3.3)	**3.69**	(N_r) (6.1.2)
6.1.3 Self-initiated time - minutes per hour per trooper, use (4.4)	**9.75**	(m_s) (6.1.3)
6.1.4 Average number of troopers required per day to meet patrol time requirements, use (5.5) . . .	**10.20**	(N_p) (6.1.4)
6.1.5 Average total number of on-duty troopers required per day for all patrol activities within the APA, one trooper per unit, use the formula below	**21.12**	* (6.1.5)

$$\text{Average Total Number of On-Duty Troopers Per Day (6.1.5)} = \frac{N_r\ (6.1.2) + N_p\ (6.1.4)}{1 - \frac{m_a\ (6.1.1)}{60} - \frac{m_s\ (6.1.3)}{60}}$$

6.2 Adjustment for Two-Trooper Patrols

NOTE: If two-trooper patrols are not used, enter (6.1.5) into (6.2.4) and continue with Section 6.3.

6.2.1 Percentage of time patrol units within the APA are staffed with two troopers **0.00** (6.2.1)

6.2.2 Fraction of time patrol units within the APA are staffed with two troopers, divide: (6.2.) ÷ 100 . . . . . **0.00** (6.2.2)

6.2.3 Adjustment factor: average number of troopers per unit, add: 1 + (6.2.2) **1.00** (6.2.3)

6.2.4 Average total number of on-duty troopers required per day for all patrol activities, multiply: (6.1.5) x (6.2.3) . . . . . (6.2.4)

6.3 Adjustment for Minimum Staffing Levels

Note: If minimum staffing levels are not used, enter (6.2.4) into (6.3.2) and continue with Worksheet 7.

6.3.1 Average minimum number of on-duty troopers required for all patrol activities, based on agency policy . . . . . (N_{min}) (6.3.1)

6.3.2 Average daily number of on-duty troopers required for all patrol activities (N_o), select the: larger of (6.2.4) and (6.3.1) . . (6.3.2)

WORKSHEET 7: Special Assignments and Field Supervision

Objective: Determine (1) the revised number of on-duty troopers required per day because of troopers on special assignments and (2) the number of field supervisors required.

Method: The number of troopers for special assignments is based on the number of specialists assigned by the agency and the percentage of time each spends on field patrol activities. The number of field supervisors is based on the span of supervision (set by agency policy) and the percentage of field supervisor on-duty time spent on patrol activities.

7.1 Number of Full-Time, On-Duty Troopers Required per Day, Adjusted for Field Supervisors

7.1.1 Average number of troopers to be supervised by each field supervisor, use (1.2.3)	**10.0**	(7.1.1)
7.1.2 Percentage of field supervisor on-duty time spent on patrol activities (a number between 0 and 100), use (1.2.4)	**60.0**	(7.1.2)
7.1.3 Fraction of field supervisor on-duty time spent on patrol activities, divide: (7.1.2) ÷ 100	**0.60**	(7.1.3)
7.1.4 Total number of on-duty troopers required per day within the APA ($\mathbf{N_o}$) for all patrol activities, use (6.3.2)	**21.12**	($\mathbf{N_o}$) (7.1.4)
7.1.5 Adjustment factor ($\mathbf{K_f}$),	**0.94**	($\mathbf{K_f}$)

use formula below . . . .))))))))))-
(7.1.5)

Adjustment Factor (K_f) (7.1.5) =))
Troopers Per Field Sup. (7.1.1) + Fraction of Field Sup. Time on Patrol (7.1.3)
Troopers Per Field Sup. (7.1.1)

7.1.6 Adjusted daily number of full-time, on-duty troopers (N_{ao}) required per day, use formula below . . . . .

6444444444447
5 **19.93** 5 (N_{ao})
9444444444448
(7.1.6)

Adjusted Number of Full-Time, On-Duty Troopers Per Day (N_{ao}) (7.1.6) = K_f x No. of On-Duty Troopers Per Day (N_o) (7.1.4)

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NOTE: If no special assignment personnel are to be included, enter (7.1.6) into (7.2.4) and continue with Section 7.3. If special assignment personnel are to be included, continue with Section 7.2.

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7.2 Number of On-Duty Troopers Required Per Day, Adjusted for Special Assignment Personnel

7.2.1 Special Assignment 1

+))))))))))))))))))))))),
* **Crime Prevention** *

7.2.1.1 Assign. 1 name . .))))))))))))))))))))))-
(7.2.1.1)

7.2.1.2 Average number of <u>on-duty</u> troopers per day on specialized assignment 1 . . . . . .

+))))))))))),
* **3.0** * (N_{s1})
.))))))))))-

(7.2.1.2)

7.2.1.3 Percentage of on-duty time spent on patrol activities by troopers assigned to special assignment 1 (a number between 0 and 100) . . . .

+)))))))))),
* **5.00** *
.)))))))))))-
(7.2.1.3)

7.2.1.4 Percentage of on-duty time spent on non-patrol activities by troopers assigned to special assignment 1, subtract: 100 - (7.2.1.3) . . . . .

+)))))))))),
* **95.00** *
.)))))))))))-
(7.2.1.4)

7.2.1.5 Fraction of on-duty time spent on non-patrol activities by troopers assigned to special assignment 1, divide: (7.2.1.4) ÷ 100 . . . . .

+)))))))))),
* **0.95** * ($\mathbf{f_{s1}}$)
.)))))))))))-
(7.2.1.5)

7.2.1.6 Adjusted daily number of on-duty troopers assigned to special assignment 1, use formula below . . . . . | 2.69 | (N_{as1}) (7.2.1.6)

Adjusted Number On-Duty Troopers, Special Assignment 1 (N_{as1}) (7.2.1.6)	=	Number On-Duty Troopers S.A. 1 (N_{s1}) (7.2.1.2)	x	Fraction Time On Non-Patrol Activities (f_{s1}) (7.2.1.5)	x	Adjustment Factor (K_f) (7.1.5)

NOTE: If personnel for a second special assignment are to be included, complete steps (7.2.2.1) through (7.2.2.6). If not, enter zeros for steps (7.2.2.6) and (7.2.3.6) and continue with Step 7.2.4.

7.2.2 Special Assignment 2

7.2.2.1 Assign. 2 name . | _____ | (7.2.1.1)

7.2.2.2 Average number of <u>on-duty</u> troopers per day on specialized assignment 2 . . . . . | --- | (N_{s2}) (7.2.2.2)

7.2.2.3 Percentage of on-duty time spent on patrol activities by troopers assigned to special assignment 2 (a number between 0 and 100) . . . . | --- | (7.2.2.3)

7.2.2.4 Percentage of on-duty time spent on non-patrol activities by troopers assigned to special assignment 2, subtract: 100 - (7.2.2.3) . . . . . | --- | (7.2.2.4)

7.2.2.5 Fraction of on-duty time spent on non-patrol activities by troopers assigned to special assignment 2, divide: (7.2.2.4) ÷ 100 . . . . . → (f_{s2}) (7.2.2.5)

7.2.2.6 Adjusted daily number of on-duty troopers assigned to special assignment 2, use formula below . . . . . → (N_{as2}) (7.2.2.6)

Adjusted Number On-Duty Troopers, Special Assignment 2 (N_{as2}) (7.2.2.6) = Number On-Duty Troopers S.A. 2 (N_{s2}) (7.2.2.2) x Fraction Time On Non-Patrol Activities (f_{s2}) (7.2.2.5) x Adjustment Factor (K_f) (7.1.5)

NOTE: If personnel for a third special assignment are to be included, complete steps (7.2.3.1) through (7.2.3.6). If not, enter zero for step (7.2.3.6) and continue with Step 7.2.4.

7.2.3 Special Assignment 3

7.2.3.1 Assign. 3 name . → (7.2.3.1)

7.2.3.2 Average number of <u>on-duty</u> troopers per day on specialized assignment 3 . . . . . → (N_{s3}) (7.2.3.2)

7.2.3.3 Percentage of on-duty

time spent on patrol activities by troopers assigned to special assignment 3 (a number between 0 and 100) . . . (7.2.3.3)

7.2.3.4 Percentage of on-duty time spent on non-patrol activities by troopers assigned to special assignment 3, subtract: 100 - (7.2.3.3) . . . . . (7.2.3.4)

7.2.3.5 Fraction of on-duty time spent on non-patrol activities by troopers assigned to special assignment 3, divide: (7.2.3.4) ÷ 100 . . . . . (f_{s3}) (7.2.3.5)

7.2.3.6 Adjusted daily number of on-duty troopers assigned to special assignment 3, use formula below . . . . . (N_{as3}) (7.2.3.6)

Adjusted Number On-Duty Troopers, Special Assignment 3 (N_{as3}) (7.2.3.6) = Number On-Duty Troopers S.A. 3 (N_{s3}) (7.2.3.2) x Fraction Time On Non-Patrol Activities (f_{s3}) (7.2.3.5) x Adjustment Factor (K_f) (7.1.5)

7.2.4 Adjusted total daily number of on-duty troopers required per day, use formula below . . . . . (N_{ot}) (7.2.4)

Adjusted Total Number of On-Duty Troopers Per Day (N_{ot}) (7.2.4) = N_{ao} (7.1.6) + N_{as1} (7.2.1.6) + N_{as2} (7.2.2.6) + N_{as3} (7.2.3.6)

7.3 Total Number of On-Duty Field Supervisors Required Per Day for the Adjusted Number of On-Duty Troopers

7.3.1 Total number of on-duty field supervisors (N_{os}) required per day, day, divide: (7.2.4) ÷ (7.1.1) . . . [**2.26**] (N_{os})
(7.3.1)

WORKSHEET 8: Total Staff Requirements

Objective: Determine total staff needed to support the required daily on-duty field personnel.

Method: Use the shift relief factor, daily on-duty staff requirements, and the number of staff and command positions based on agency policy.

8.1 On-Duty Troopers and Field Supervisors Required per Day

8.1.1	Total number of on-duty troopers per day within the APA, use (7.2.4)	**22.62** (N_{ot}) (8.1.1)
8.1.2	Total number of on-duty field supervisors per day within the APA, use (7.3.1)	**2.26** (N_{os}) (8.1.2)

8.2 Shift Relief Factor

8.2.1	Shift length (hours), use (1.2.1)	**8.0** (8.2.1)
8.2.2	Total hours on one shift during one year, multiply: 365 x (8.2.1)	**2,920.0** (H_t) (8.2.2)

8.2.3 Average work week (average number of paid hours per week per officer), use (1.2.2.1) . . .

+))))))))))),
* **40.0** * (**AWW**)
.)))))))))))-
(8.2.3)

8.2.4 Average number of paid hours of work per year per officer, use formula below . . . .

+))))))))))),
* **2,085.71** * ($\mathbf{H_y}$)
.)))))))))))-
(8.2.4)

$$\text{Average Number of Paid Hours of Work per Year per Officer } (\mathbf{H_y}) = \frac{365 \times \text{AWW (8.2.3)}}{7}$$

8.2.5 Average number of benefit (paid) hours off per year per officer, use (1.2.2.2) . . . .

+))))))))))),
* **242.2** * ($\mathbf{H_b}$)
.)))))))))))-
(8.2.5)

8.2.6 Average number of on-duty hours on temporary assignments (non-patrol) per officer per year, use (1.2.2.3) . . . . .

+))))))))))),
* **48.3** * ($\mathbf{H_{ta}}$)
.)))))))))))-
(8.2.6)

8.2.7 Average number of on-duty, hours on patrol per year per officer, use formula below . . . .

+))))))))))),
* **1,795.21** * ($\mathbf{H_{np}}$)
.)))))))))))-
(8.2.7)

$$\text{Average Number of On-Duty Hours On Patrol per Year per Officer } (\mathbf{H_{np}}) = \underset{(8.2.4)}{H_y} - \underset{(8.2.5)}{H_b} - \underset{(8.2.6)}{H_{ta}}$$

8.2.8 Shift relief factor divide: (8.2.2) ÷ (8.2.7) . . . .

+))))))))))),
* **1.627** * (**SRF**)
.)))))))))))-
(8.2.8)

444444444444444444444444444444444444444444444444444444444444

8.3 Total Number of Required Troopers and Field Supervisors Within the APA

8.3.1 Total number of troopers,

+))))))))))),
* **36.79** * ($\mathbf{N_t}$)

multiply: (8.1.1) x (8.2.8) . . . .)))))))))))-
(8.3.1)

8.3.2 Total number of field +))))))))))),
supervisors, multiply: * **3.68** * (N_s)
(8.1.2) x (8.2.8) . . . .)))))))))))-
(8.3.2)

8.3.3 Total number of troopers and +))))))))))),
field supervisors, add: * **40.46** *
(8.3.1) + (8.3.2) . . . .)))))))))))-
(8.3.3)

44444444444444444444444444444444444444444444444444444444444444

8.4 Number of Staff and Command Personnel - Agency Policy

Select number of staff and command
personnel required for the +))))))))))),
number of troopers and field * **4.0** *
supervisors given in (8.3.3) . . . .)))))))))))-
(8.4)

44444444444444444444444444444444444444444444444444444444444444

8.5 Total Staff Requirements for the APA

+))))))))))),
8.5.1 Number of troopers within * **36.79** * (N_t)
the APA, use (8.3.1) . . . .)))))))))))-
(8.5.1)

+))))))))))),
8.5.2 Number of field supervisors * **3.68** * (N_s)
within the APA, use (8.3.2) . . . .)))))))))))-
(8.5.2)

8.5.3 Number of staff and +))))))))))),
command personnel * **4.0** * (N_h)
within the APA, use (8.4) . . . .)))))))))))-
(8.5.3)

8.5.4 Total required staff 6444444444447
for the APA, add: 5 **44.46** 5 (N_{tot})
(8.5.1) + (8.5.2) + (8.5.3) 9444444444448
(8.5.4)

4444444444444444444444444444444444444444444444444444444444444444

WORKSHEET 9: Allocation of Patrol Personnel Among Several APAs

Objective: Determine the appropriate number of personnel to be assigned to each APA based on the estimated PAM staffing levels for each APA.

Method: Based on the number of personnel estimated for each APA, two reallocations of current and new personnel are determined. The unconstrained allocation redistributes all personnel, both current and new, among the APAs in the same proportion as the PAM estimates. The constrained allocation restricts the allocation to only new (or reduced) personnel insuring that no APA loses staffing when new personnel are added (or that no APA gains staffing when personnel reductions are applied).

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See Chapter 4 in the Manual for the instructions for Worksheet 9.

Table 4 - 1

Worksheet for the Allocation of Patrol Personnel Among Several APAs Based on PAM Staff Estimates

Total Number of Additional (or Reduced) Personnel for All APAs (9.1.1) . . . . . **6** (**TA**)

APA	Current Staff (9.1.3)	PAM Staff Est. (9.1.5)	**Unconst Reallo.** (9.1.7)	Diff. Col. 1 - Col. 3 (9.2.1)	To Be Added (9.2.3.3) or (9.2.3.1) or (9.2.4.1) or (9.2.4.2)	Reduced (9.2.4.3)	Rounded (9.2.6)	**Constr. Reallo.** Col. 1 + Col. 7 (9.2.8)
	Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7	Col. 8
1	**13**	**11**	**11.0**	**2.0**	**0.0**	**0.0**	**0**	**13**
2	**13**	**16**	**86.0**	**-3.0**	**-3.0**	**2.3**	**2**	**15**
3	**13**	**18**	**18.0**	**-5.0**	**-5.0**	**3.8**	**4**	**17**
4								
Col. Sum	**39** (**TC**) (9.1.4)	**45** (**TE**) (9.1.6)	**45.0** (9.1.8)	**-6.0** (9.2.2)	**-8.0** (**TN**)	**6.0** (9.2.5)	**6** (9.2.7)	**45** (9.2.9)
Sum Check	**39** (**TC**) (9.1.2)		**45.0** (9.1.1) + (9.1.1) - (**TA**) (9.1.2) (**TA+TC**)	**-6.0** -1 x (9.1.1)		**6.0** (9.1.1) (**TA**)	**6** (9.1.1) (**TA**)	**45** (9.1.1) + (9.1.2) (**TA+TC**)

APPENDIX D: Derivations of the Major Formulas Used in PAM

The following ten sections contain derivations of all of the major formulas used in the PAM model and is intended for those users who wish to examine more closely the relationships between the input data and the calculated results. For some derivations, familiarity with algebraic operations is needed to follow the discussion and considerable use is made of notational shortcuts to reduce the length of each section. Since many of the notations are not used elsewhere in the Manual, definitions are supplied in each section as new terminology and variables are introduced. All page, section, and step numbers identified in the derivations refer to locations in the Manual.

APPENDIX D.1: Average Number of On-Duty Troopers (N_r) Required Per Day Within the APA To Meet the Average Daily (Obligated Time) Workload, (3.3.3)

The formula in Worksheet 3 that is used to determine the average number of on-duty troopers required per day within the APA to meet the average daily obligated time workload is given by:

$$N_r\ (3.3.3) = \frac{\text{Total Average Daily Obligated Time Workload (3.3.1)}}{\text{Shift Length (3.3.2)}} \qquad \text{(D.1.1)}$$

where obligated time refers to the time required by all patrol units to respond to and service all CFS and accidents in the APA. (See page 3-19 in the Manual for a more detailed discussion of obligated time.) The formula for N_r in Worksheet 3 is based on the assumption that all patrol units are one-trooper units only. An adjustment for two-trooper units is available in Worksheet 6.

The derivation of formula (D.1.1) is based on the recognition that, at a minimum, there must be sufficient reactive patrol resources to provide enough on-duty time (i.e., there must be enough patrol units) to respond to and service all reactive (obligated time) workload; that is,

$$\text{Total Reactive Patrol Resources} = \text{Total Reactive Workload.} \qquad \text{(D.1.2)}$$

The total reactive workload for any period of time (days) can be measured by determining the total obligated time (**TOT**) required for all CFS and accidents during the period. The total reactive patrol resources for any period of time can be expressed in hours as:

$$\text{Total Reactive Patrol Resources} = N_r \times S_1 \times D \qquad \text{(D.1.3)}$$

where:

- N_r - the average number of on-duty troopers per day,
- S_1 - shift length in hours, and

D - total number of days in the time period used to measure the total obligated time workload.

Replacing the total reactive patrol resources in (D.1.2) with (D.1.3) and replacing the total reactive workload with total obligated time (**TOT**) yields:

$$N_r \times S_1 \times D = TOT \qquad (D.1.4)$$

Solving (D.1.4) for $\mathbf{N_r}$ gives:

$$N_r = \frac{TOT}{S_1 \times D} \qquad (D.1.5)$$

The expression TOT/D equals the average daily obligated time workload (**ADOT**); that is,

$$ADOT = \frac{TOT}{D} \qquad (D.1.6)$$

Replacing TOT/D with **ADOT** in (D.1.5) yields the result (D.1.1); that is,

$$N_r\ (3.3.3) = \frac{ADOT\ (3.3.1)}{S_1\ (3.3.2)} \qquad (D.1.7)$$

APPENDIX D.2: Average Number of On-Duty Troopers ($\mathbf{N_{ppi}}$) Required Per Day To Meet the Patrol Interval Performance Requirement Objective Within the APA, (5.1.2.6), (5.1.3.6), and (5.1.4.6)

Derivation of the General Formula for Patrol Interval

The patrol interval is a measure of the intensity or level of patrol coverage of a given roadway segment. Patrol interval, measured in hours, can be described in several ways. One definition is that the patrol interval represents the average time it will take a fixed number of patrol units to drive over every roadway mile in the system. An alternative but equivalent definition is that the patrol interval indicates the average time a

stranded motorist will have to wait for a trooper, on uncommitted patrol, to drive by.

Important assumptions associated with the patrol interval are that:

- Uncommitted patrol activity occurs randomly over all roadways of the same type; that is, all roadways within each type are treated equally, and
- Uncommitted patrol activity only occurs when a patrol unit is not occupied with administrative, reactive, or self-initiated duties.

Both assumptions are important and limiting. The assumption that all roadways are patrolled equally is usually not the case because of the greater importance of some roadways than others due to traffic volume and accident experience. Basing the patrol interval on "uncommitted" or "free" patrol time (i.e., time not spent on administrative, reactive, or self-initiated activities) ignores the fact that stranded motorists may be observed and reported by units while engaged in other activities.

Calculation of the patrol interval depends on the number of roadway miles, the number of patrol units, the average patrol speed, and the amount of time spent on uncommitted patrol. The formula for determining the patrol interval is given by:

$$PI = \frac{HM}{N \times PS \times f_u} \qquad \text{(D.2.1)}$$

where:

PI - patrol interval (hours),

HM - total number of roadway miles,

N - total number of patrol units on duty,

PS - average patrol speed (MPH), and

$\mathbf{f_u}$ - fraction of time spent on uncommitted time.

The derivation of formula (D.2.1) is mostly easily shown by starting with the definition that the patrol interval represents the average amount of time that it will take a fixed number of patrol units to cover the entire roadway system. This definition can also be stated as a question: If it is known how many miles per hour all units drive collectively while on uncommitted patrol, how many hours will it take to cover the entire roadway system? The ques-

tion implies that the total roadway miles (**HM**) and the average miles driven per hour (**AHM**) by all units are known and are related to the patrol interval (**PI**) as:

$$HM = AHM \times PI \qquad \text{(D.2.2)}$$

Rearranging the terms in (D.2.2) yields:

$$PI = \frac{HM}{AHM} \qquad \text{(D.2.3)}$$

The average number of roadway miles driven per hour (**AHM**) by all units can be expressed as:

$$AHM = AM \times N \qquad (D.2.4)$$

where:

N - total number of units on duty, and

AM - average miles driven per hour per unit.

Replacing **AHM** in (D.2.3) with (D.2.4) yields:

$$PI = \frac{HM}{AM \times N} \qquad (D.2.5)$$

The average miles driven per hour by each unit (**AM**) can be expressed as:

$$AM = PS \times f_u \qquad (D.2.6)$$

where **AM**, **PS**, and $\mathbf{f_u}$ are defined above. Replacing **AM** in (D.2.5) with (D.2.6) yields formula (D.2.1). For computational purposes, however, it is advantageous to express the fraction of time spent on uncommitted time as:

$$f_u = \frac{m_u}{60} \qquad (D.2.7)$$

where $\mathbf{m_u}$ represents the average number of minutes per hour spent on uncommitted time by each unit. Dividing $\mathbf{m_u}$ by 60 yields the fraction of time spent on uncommitted time. Replacing $\mathbf{f_u}$ in (D.2.6) with (D.2.7) yields:

$$AM = PS \times \frac{m_u}{60} \qquad (D.2.8)$$

and replacing **AM** in (D.2.5) with (D.2.8) yields the final expression for **PI:**

$$PI = \frac{HM}{PS \times \frac{m_u}{60} \times N} \qquad \text{(D.2.9)}$$

Derivation of the Number of Troopers ($\mathbf{N}_{ppi}$) Required to Meet the Patrol Interval Performance Objective, Steps (5.1.2.6), (5.1.3.6), and (5.1.4.6)

To determine how many troopers are needed to achieve a particular patrol interval performance objective for a particular roadway type requires solving (D.2.9) for **N**; i.e.,

$$N = \frac{HM}{PS \times \frac{m_u}{60} \times PI} \qquad \text{(D.2.10)}$$

To obtain the minimum number of units, let $m_u = 60$ which reduces (D.2.10) to:

$$N = \frac{HM}{PS \times PI} \qquad \text{(D.2.11)}$$

Formula (D.2.11) indicates the minimum number of patrol units that would be needed to meet the patrol interval objective.

Formula (D.2.11) is based on the assumption that the roadway system is patrolled 24 hours a day everyday (i.e., 168 hours per week). To account for reduced coverage (i.e., for coverage that is less than 168 hours per week), multiply formula (D.2.11) by WC/168; that is,

$$N = \frac{HM}{} \times \frac{WC}{} \qquad \text{(D.2.12)}$$

$$PS \times PI \qquad 168$$

where **WC** represents the total hours of coverage per week.

To determine the number of on-duty troopers that will be required per day ($\mathbf{N_{ppi}}$), use the relationship:

$$N_{ppi} = N \times \frac{24}{S_1} \qquad \text{(D.2.13)}$$

where:

N - number of patrol units given in (D.2.12), and

$\mathbf{S_1}$ - shift length in hours.

Substituting (D.2.12) for **N** in (D.2.13) and simplifying yields:

$$N_{ppi} = \frac{HM \times WC}{7 \times PS \times S_1 \times PI} \qquad \text{(D.2.14)}$$

which is the formula used in Section 5.1 to determine the number of troopers required to meet patrol interval performance objectives for a particular roadway type. The number of troopers for three roadway types are shown in Worksheet 5 in steps (5.1.2.6), (5.1.3.6), and (5.1.4.6). The sum of these results is recorded in (5.1.5)

APPENDIX D.3: Total Number of Troopers (N_{pir}) Required Per Day Within the APA To Provide Immediate Response To the Performance Objective Percentage of CFS, Accidents, and Self-Initiated Activities, (5.2.8)

In the PAM model, the appearance and servicing of CFS (i.e., accidents and other dispatched incidents) and self-initiated activities (e.g., motorist assists) are treated as a simple multiserver queuing process. CFS and self-initiated activities are assumed to occur randomly (i.e., as a Poisson process) and the service times associated with each activity are assumed to be independent and exponentially distributed.

The term "exponentially-distributed service times" describes the particular mathematical distribution or formula that is used to describe the nature of the service times (e.g., what would the histogram of a sample of service times look like). A key property of exponentially-distributed service times is that the likelihood (or probability) of service time t_1 will be less than the likelihood (or probability) of service time t_2 if $t_1 > t_2$. This property implies that the individual bars in the histogram of sample service times will be smaller for longer service times. Field experience indicates that exponentially-distributed service times are appropriate for describing many operations; for example, the lengths of telephone calls, the times required to complete transactions with bank tellers, the times required to checkout at grocery stores, and the average service times associated with dispatched CFS.

In a standard, steady-state queuing formulation with these assumptions and a fixed number of servers (i.e., a fixed number of patrol troopers), the average number of busy troopers at any given time (N_b) is given by:

$$N_b = CR \times ST \qquad \text{(D.3.1)}$$

where **CR** represents the number of activities per hour and **ST** represents the average service time in hours.

The likelihood or probability that all of the troopers will be busy (P_{sat}) when the next activity occurs is called the "probability of saturation" and is given by Erlang's formula found in many introductory texts on queuing theory:

$$P_{sat} = \frac{N_b{}^N t}{N_t! \times (1 - N_b/N_t)} P_o \qquad \text{(D.3.2)}$$

where N_t represents the total number of troopers in the area and the term $N_b^{N}t$ represents N_b raised to the N_t th power, and

$$P_o = \left[\sum_{k=0}^{N_t-1} \frac{N_b^k}{k!} + \frac{N_b^{Nt}}{N_t! \times (1 - N_b/N_t)} \right]^{-1} \qquad \text{(D.3.3)}$$

Note that unless N_t equals or exceeds N_b, there will not be enough troopers to handle the workload and the system will be continuously "saturated;" that is, the queue (or stack) will grow larger and larger. Readers who wish to examine the derivation of these formulas as referred to any standard text on queueing theory or operations research such as Introduction to Operations Research by Hillier and Lieberman (Holden-Day, Inc., 1967).

The likelihood or probability that at least one trooper will be available (P_{avail}) when the next activity occurs is given by:

$$P_{avail} = 1 - P_{sat} \qquad \text{(D.3.4)}$$

For this derivation, the total number of troopers (N_t) available for assigned and self-initiated activities consists of the total number of on-duty troopers for reactive activities (N_r) determined in Worksheet 3, the total number of on-duty troopers for self-initiated activities (N_s), and the total number of on-duty troopers for uncommitted patrol activities (N_p); i.e.,

$$N_t = N_r + N_s + N_p \qquad \text{(D.3.5)}$$

Troopers working on administrative activities (N_a) are assumed not to be available for field assignments. The number of on-duty troopers required for self-initiated activities per day can be determined from the number of on-duty troopers required per day for reactive activities (N_r), the number of on-duty troopers required per day for uncommitted patrol activities (N_p), the average number of minutes of administrative time per hour per trooper (m_a), and the average number of minutes per hour per trooper spent on self-initiated activities (m_s). In the PAM model, the number of troopers assigned to each category: administrative, reactive, self-initiated, and uncommitted patrol is proportional to the time spend per hour on each activity; i.e.,

$$\frac{N_a}{N_{tot}} = \frac{m_a}{60} \qquad \frac{N_r}{N_{tot}} = \frac{m_r}{60}$$

(D.3.6)

$$\frac{N_s}{N_{tot}} = \frac{m_s}{60} \qquad \frac{N_p}{N_{tot}} = \frac{m_p}{60}$$

where:

N_a - number of on-duty troopers working on administrative activities,

N_s - number of on-duty troopers working on self-initiated activities,

N_{tot} - total number of on-duty troopers,

m_r - average number of minutes spend per hour per trooper on reactive activities,

m_p - average number of minutes spend per hour per trooper on uncommitted patrol activities,

and

$$N_{tot} = N_r + N_p + N_a + N_s, \qquad \text{(D.3.7)}$$

and

$$60 = m_r + m_p + m_a + m_s . \qquad \text{(D.3.8)}$$

Rearranging the terms in (D.3.6) yields:

$$\frac{N_s}{m_s} = \frac{N_r}{m_r} = \frac{N_p}{m_p} = \frac{N_{tot}}{60}. \qquad \text{(D.3.9)}$$

Noting that the following is true:

$$\frac{N_r + N_p}{m_r + m_p} = \frac{N_{tot}}{60} \qquad \text{(D.3.10)}$$

and combining (D.3.9) and (D.3.10) yields:

$$\binom{N_s}{m_s} = \binom{N_r + N_p}{m_r + m_p} \qquad \text{(D.3.11)}$$

Using (D.3.8) to replace $m_r + m_p$ with $60 - m_a - m_s$ in (D.3.11) yields:

$$\binom{N_s}{m_s} = \binom{N_r + N_p}{60 - m_a - m_s} \qquad \text{(D.3.12)}$$

Using (D.3.12) to solve for $\mathbf{N_s}$ yields:

$$N_s = K_s \times (N_r + N_p) \qquad \text{(D.3.13)}$$

where $\mathbf{K_s}$ equals:

$$K_s = \binom{m_s}{60 - m_a - m_s} \qquad \text{(D.3.14)}$$

Replacing $\mathbf{N_s}$ in (D.3.5) with (D.3.13) and rearranging yields:

$$N_t = N_r + K_s \times N_r + K_s \times N_p + N_p \qquad \text{(D.3.15)}$$

The right side of formula (D.3.15) consists of four terms. Three of the terms, $N_r + (K_s \times N_r) + (K_s \times N_p)$, represent the troopers that are busy on assigned and self-initiated activities; i.e.,

$$N_b = N_r + K_s \times N_r + K_s \times N_p \qquad \text{(D.3.16)}$$

where $\mathbf{N_r}$ represents the troopers on reactive activities and $(K_s \times N_r) + (K_s \times N_p)$ represents the troopers on self-initiated activities. The only troopers represented in formula in (D.3.15) that are not busy or available are represented by $\mathbf{N_p}$. If no on-

duty troopers are provided for uncommitted patrol activities (i.e, if $N_p = 0$), then $N_t = N_r + (K_s \times N_r)$ which says that all troopers in the field are busy. The number of on-duty troopers required for reactive and self-initiated activities, $N_r + (K_s \times N_r)$, is the <u>minimum</u> number of troopers required to handle the CFS and self-initiated activities. Hence, by definition, if only $N_r + (K_s \times N_r)$ troopers are available, every trooper will be busy for 60 minutes an hour which is equivalent to $P_{sat} = 1$ and $P_{avail} = 0$.

As troopers are added for uncommitted patrol activities (i.e., as $\mathbf{N_p}$ becomes greater zero), $\mathbf{N_t}$ increases and the hourly reactive and self-initiated workload for each trooper becomes less than 60 minutes per hour. As this happens, $\mathbf{P_{sat}}$ decreases and $\mathbf{P_{avail}}$ increases. As more troopers are added, $\mathbf{P_{avail}}$ increases until it equals or exceeds the immediate response performance objective expressed as a probability ($\mathbf{P_{obj}}$); that is, $\mathbf{N_p}$ is increased until

$$P_{avail} \geq P_{obj} \qquad \text{(D.3.17)}$$

where:

$$P_{obj} = \frac{PIR\%}{100}$$

and **PIR%** represents the immediate response performance objective expressed as percent entered by the user in Step 5.2.6.

Because of the complexity of formulas (D.3.2) and (D.3.3), it is not possible to derive a closed expression for $\mathbf{N_p}$ based on $\mathbf{N_r}$, $\mathbf{K_s}$, and $\mathbf{P_{obj}}$. To overcome this difficulty, the PAM manual uses a table look-up procedure to determine $\mathbf{N_p}$. Two options are available. The first option, described in Section 5.2 uses Table 3-1. This simplified procedure is based on three assumptions. The first is that $\mathbf{K_s} = 0.25$. Use of this assumption permits the use of only one table and avoids the necessity for the user to calculate $\mathbf{K_s}$. Using $K_s = 0.25$ is equivalent to using values of 9 and 15 minutes per hour respectively for $\mathbf{m_a}$ and $\mathbf{m_s}$. The second assumption is that staffing is uniform over all shifts. The third assumption is that the same performance objective (i.e., **PIR%**) is used for each shift. These assumptions avoid the necessity of determining separate $\mathbf{N_p}$ values for each shift.

To use the procedure in Section 5.2, the user must determine the average number of on-duty troopers per shift ($\mathbf{N_{rs}}$) in steps (5.2.1) through (5.2.5) and select an immediate response performance objective percent (**PIR%**)in Step (5.2.6). Once $\mathbf{N_{rs}}$ and **PIR%** are known, Table 3-1 is used in Step (5.2.7) to estimate the number of on-duty patrol troopers that are needed on each shift ($\mathbf{N_{pir}}$) to meet the

immediate response objective. The total number of on-duty troopers for uncommitted patrol per day, Step (5.2.8), is obtained by multiplying the average number required per shift by the effective number of shifts per day.

If any of the simplifying assumptions used in Section 5.2 are not valid, the user can use the supplemental worksheet in Appendix A in the Manual to estimate $\mathbf{N_{pir}}$. This worksheet requires the use of $\mathbf{m_a}$ and $\mathbf{m_s}$, determined in worksheets 2 and 4, to calculate $\mathbf{K_s}$ (Step A.5.1). The value for $\mathbf{K_s}$ is used to select the appropriate table based on the guidelines given on page A-6. The number of troopers required for uncommitted patrol is determined for each shift (steps (A.6.1.3), (A.6.2.3), and (A.6.3.3)), and the results are added together to obtain the total daily on-duty requirement for uncommitted patrol, Step (A.7).

The values in Table 3-1 and tables A-1 through A-10 were determined using formulas (D.3.2), (D.3.3), (D.3.4), and (D.3.15) with the following logic:

- For a range of values (0.05 - 5.00) for the average number of on-duty troopers for reactive and self-initiated activities on each shift ($\mathbf{N_{ri}}$) and a range of values (0.0 - 1.0) for $\mathbf{K_s}$, calculate $\mathbf{P_{avail}}$ values for integer values of Nt beginning with the smallest value of $\mathbf{N_t}$ such that $N_t \geq N_r$.

- For each value of $\mathbf{N_t}$, determine the number of troopers available for uncommitted patrol ($\mathbf{N_{pir}}$) based on (D.3.16); i.e.,

$$N_{pir} = \frac{N_t - (1 + K_s) \times N_r}{(1 + K_s)} \quad \text{(D.3.18)}$$

Increase $\mathbf{N_t}$ until $P_{avail} \geq .995$.

- Estimate N_{pir} for specific values of N_r, P_{avail}, and K_s by interpolating between the calculated values for N_{pir} and P_{avail} for specific values for K_s. Each value of K_s represents a separate table in Appendix A. Within each table, each estimated value for N_{pir} corresponds to specific values for N_r and P_{avail}.

APPENDIX D.4: Average Number of On-Duty Troopers (N_{pap}) Required Within the APA To Meet the Average Travel Time Performance Objective for Area Patrol, (5.3.6.3)

In the PAM model, the average number of on-duty troopers required per day to meet the average travel time performance objective for area patrol is given by:

$$N_{pap} = \left(\frac{40}{PTT \times RS} \right)^2 \times \frac{A \times WC}{7 \times S_1} \qquad \text{(D.4.1)}$$

where:

N_{pap} - average number of troopers required to meet the travel time performance objective for area patrol,

A - area (square miles) of the APA,

WC - coverage (hours) per week,

NS - number of shifts per day,

PTT - average travel time (minutes) performance objective,

RS - average response speed (MPH), and

S_1 - shift length (hours).

Formula (D.4.1) is based on the so-called "square root law" which can be used to estimate the average travel distance (**D**) for a responding police unit in an area of size A with N available units. The generic formula is given by:

$$D = K \times \frac{\sqrt{A}}{\sqrt{N}} \qquad \text{(D.4.2)}$$

where:

D - average distance (miles),

K - a constant based on the geography of the area,

A - the area of the region (square miles), and

N - the number of police units available.

Using the time (**T**), speed (**S**), and distance (**D**) relationship from basic physics; i.e.,

$$T = \frac{D}{S} \qquad \text{(D.4.3)}$$

and replacing **D** in (D.4.3) with (D.4.2) yields:

$$T = \frac{K \times \sqrt{A}}{S \times \sqrt{N}} \qquad \text{(D.4.4)}$$

Under certain conditions, Larson (Urban Police Patrol Analysis, MIT Press, 1972) found that a value of 2/3 for the constant in (D.4.2) gives good results. (Key conditions are relatively low workload levels, uniformity of workload over the area, and approximately equal travel times in all directions.) Putting 2/3 in for **K** in formula (D.4.4) and multiplying by 60 to change travel time to minutes yields:

$$T = \frac{60 \times 2 \times \sqrt{A}}{3 \times S \times \sqrt{N}} \qquad \text{(D.4.5)}$$

Simplifying expression (D.4.5) yields:

$$T = \frac{40 \times \sqrt{A}}{S \times \sqrt{N}} \qquad \text{(D.4.6)}$$

Solving formula (D.4.6) for **N** yields:

$$N = \left(\frac{40}{T \times S} \right)^2 \times A \qquad \text{(D.4.7)}$$

Replacing speed (**S**) with the average response speed (**RS**) and time (**T**) with the average travel time performance objective (**PTT**) yields:

$$N = \left(\frac{40}{PTT \times RS} \right)^2 \times A \qquad \text{(D.4.8)}$$

which indicates the number of patrol units required each day to meet the performance travel time objective.

Formula (D.4.8) is based on the assumption that the area is patroled 24 hours a day, 7 days a week (i.e., 168 hours per week). To account for reduced coverage (i.e., less than 168 hours per week), (D.4.8) can by multiplied by WC/168; that is,

$$N = \left(\frac{40}{PTT \times RS} \right)^2 \times A \times \frac{WC}{168} \qquad \text{(D.4.9)}$$

where **WC** represents the total hours of coverage per week.

Since each patrol unit represents one trooper, the total number of troopers needed per day for area patrol is given by:

$$N_{pap} = N \times \frac{24}{S_1} \qquad \text{(D.4.10)}$$

where **N** is the number of units calculated in (D.4.9) and S_1 is the shift length in hours. Replacing **N** in (D.4.10) with (D.4.9) and simplifying yields:

$$N_{pap} = \left(\frac{40}{PTT \times RS} \right)^{2} \times \frac{A \times WC}{7 \times S_1} \qquad \text{(D.4.11)}$$

which is the formula given in (D.4.1). In Section 5.3, formula (D.4.11) is used in Step (5.3.6) to determine the number of troopers required to meet the target travel time for area patrol.

APPENDIX D.5: Average Number of On-Duty Troopers (N_{plp}) Required Within the APA To Meet the Average Travel Time Performance Objective for Line Patrol, (5.3.7) and (B.6)

In the PAM model, the average number of troopers required to meet the average travel time performance objective for line patrol is given by:

$$N_{plp} = \frac{20 \times L \times WC}{7 \times RS \times PTT \times S_1} \quad \text{(D.5.1)}$$

where:

N_{plp} - average number of troopers required to meet the travel time performance objective for line patrol,

L - roadway miles in the line patrol segment,

NS - number of shifts per day,

RS - average response speed (MPH),

PTT - average travel time (minutes) performance objective,

WC - coverage (hours) per week, and

S_1 - shift length (hours).

The average travel distance to an incident on a roadway segment patrolled by one unit is given by:

$$D = \frac{L}{3} \quad \text{(D.5.2)}$$

where **D** represents the distance traveled in miles and **L** represents the number of miles in the roadway segment. The basis for formula (D.5.2) is observation that if calls-for-service occur uniformly over the roadway segment and the unit patrols uniformly over the segment, then the average distance between the unit and the location of the CFS is equivalent to the expected difference (or range)

in a sample of two observations drawn from a uniform probability density function over the interval [0,L].

Using the time (**T**), distance (**D**), and speed (**S**) relationship, D = S x T, and solving for **T** yields:

$$T = \frac{D}{S} \qquad \text{(D.5.3)}$$

Replacing **D** in (D.5.3) with formula (D.5.2) and multiplying by 60 to calculate travel time in minutes yields:

$$T = \frac{60 \times L}{3 \times S} \qquad \text{(D.5.4)}$$

Assuming that **N** units are used over the entire roadway segment and each unit is assigned to a subsegment approximately equal to 1/N of the entire segment, then the average travel time formula for each subsegment becomes:

$$T = \frac{60 \times (L/N)}{3 \times S} \qquad \text{(D.5.5)}$$

Solving (D.5.5) for **N** and simplifying yields:

$$N = \frac{20 \times L}{S \times T} \qquad \text{(D.5.5)}$$

Replacing speed (**S**) with the average response speed (**RS**) and time (**T**) with the travel time performance objective for line patrol (**PTT**) in (D.5.6) yields:

$$N = \frac{20 \times L}{RS \times PTT} \qquad \text{(D.5.6)}$$

Formula (D.5.6) indicates the minimum number of units (**N**) that are required each day to meet the travel time objective (**PTT**) for line patrol.

Formula (D.5.6) is based on the assumption that the roadway segment is patroled 24 hours per day, 7 days a week (i.e, 168 hours per

week). To account for reduced coverage (i.e., less than 168 hours per week), multiply (D.5.6) by WC/168; that is,

$$N = \frac{20 \times L}{RS \times PTT} \times \frac{WC}{168} \qquad \text{(D.5.7)}$$

where **WC** represents the total hours of coverage per week.

Since each patrol unit has only one trooper, the number of on-duty troopers required per day ($\mathbf{N_{plp}}$) equals:

$$N_{plp} = N \times \frac{24}{S_1} \qquad \text{(D.5.8)}$$

where **N** is the number of units calculated in (D.5.7) and $\mathbf{S_1}$ is the shift length in hours. Substituting (D.5.7) for **N** in (D.5.8) and simplifying yields:

$$N_{plp} = \frac{20 \times L \times WC}{7 \times RS \times PTT \times S_1} \qquad \text{(D.5.9)}$$

Formula (D.5.9) is used in the supplemental worksheet in Appendix B in the Manual and the result is entered in Step (5.3.7).

APPENDIX D.6: Average Total Number of On-Duty Troopers (**N**) Required Per Day for All Patrol Activities Within the APA, One Trooper Per Unit, (6.1.5)

Introduction

The basic formula in the PAM model, used to derive the average daily number of on-duty troopers, is given by:

$$N = \frac{N_r + N_p}{1 - \frac{m_a}{60} - \frac{m_s}{60}} \qquad \text{(D.6.1)}$$

where:

- **N** - the average number of on-duty troopers per day (i.e., per 24-hour period),
- $\mathbf{N_r}$ - the average number of on-duty troopers required per day for reactive activities,
- $\mathbf{N_p}$ - the average number of on-duty troopers required per day for uncommitted patrol activities,
- $\mathbf{m_a}$ - average number of minutes spend per hour per trooper on administrative activities, and
- $\mathbf{m_s}$ - average number of minutes spend per hour per trooper on self-initiated activities.

Four Workload Components

Derivation of formula (D.6.1) is based on the assumption that the average total number of on-duty troopers required per day (**N**) consists of four components; that is,

$$N = N_r + N_p + N_s + N_a \qquad \text{(D.6.2)}$$

where **Nt**, **Nr**, and **Np** are defined above and

- $\mathbf{N_s}$ - the average number of on-duty troopers required per day for self-initiated activities, and
- $\mathbf{N_a}$ - the average number of on-duty troopers required per day for administrative activities.

Much of the PAM model is devoted to determining each of the four components identified above. The derivation of formula (D.6.1) is based on the procedures that are used to determine the number of troopers for each component. The procedure for each component is presented below.

Reactive and uncommitted patrol activities. In the PAM model, the number of on-duty troopers required per day for reactive activities ($\mathbf{N}_r$) depends on two measures: (1) the total obligated time per day and (2) the shift length of the agency. Neither measure is dependent upon the total number of troopers (**N**) that are present. The number of on-duty troopers required per day for uncommitted patrol activities ($\mathbf{N}_p$) is based on the availability of troopers for reactive and self-initiated activities and trooper visibility for deterrence. The PAM model offers several options for determining $\mathbf{N}_p$ based on the number of roadway miles, patrol speed, patrol interval performance objectives set by the agency, area of the jurisdiction, response speed, and the number of on-duty troopers for reactive activities. Regardless of which option is used, all are independent of the total number of on-duty troopers (**N**). Hence, for both reactive and uncommitted patrol activities, all of the workload measures are independent of the number of troopers that are available and, as a result, values for $\mathbf{N}_r$ and $\mathbf{N}_p$ can be obtained using historical data regardless of the staffing levels of the agency in the past.

Self-initiated and administrative activities. In contrast to the procedures used to determine $\mathbf{N}_r$ and $\mathbf{N}_p$, the workload measures for $\mathbf{N}_s$ and $\mathbf{N}_a$ used in the PAM model are not independent of the number of on-duty troopers (**N**) that are present. The reason for this is the fact that for virtually all law enforcement agencies the amount of work that is recorded for administrative and self-initiated activities is, in fact, directly related to how many troopers are on-duty. The validity of this assertion is based on the following observations:

- Associated with each trooper is a certain amount of time that does not fall into either the reactive or self- initiated or nuncommitted patrol categories. As a result, the total administrative time for an agency is not fixed, but rather increases or decreases as the number of troopers increases or decreases.

- The total time devoted to self-initiated activities is also directly related to the number of troopers in the field; that is, as the number of troopers increases, the amount of self-initiated work increases. This occurs because the fraction of self-initiated work that can be performed with existing patrol resources is usually minor when compared to the total self-initiated work that could be pursued. As a

result, there is, potentially, enough self-initiated work to absorb even a doubling or tripling of existing patrol resources.

Determination of $\mathbf{N_s}$ and $\mathbf{N_a}$

The dependency of $\mathbf{N_s}$ and $\mathbf{N_a}$ upon the average total number of on-duty troopers per day ($\mathbf{N}$) can be expressed as:

$$N_s = f_s \times N \qquad \text{(D.6.3)}$$

and

$$N_a = f_a \times N \qquad \text{(D.6.4)}$$

where:

- $\mathbf{f_s}$ - fraction of time spend on self-initiated activities, and
- $\mathbf{f_a}$ - fraction of time spend on administrative activities.

Inserting expressions (D.6.3) and (D.6.4) into (D.6.2) above yields:

$$N = N_r + N_p + (f_s \times N) + (f_a \times N) \qquad \text{(D.6.5)}$$

Solving (D.6.5) for $\mathbf{N}$ yields:

$$N = \frac{Nr + N_p}{1 - f_s - f_a} \qquad \text{(D.6.6)}$$

The fractions $\mathbf{f_s}$ and $\mathbf{f_a}$ can be expressed as:

$$f_s = \frac{m_s}{60} \qquad \text{(D.6.7)}$$

and

$$f_a = \frac{m_a}{60} \qquad \text{(D.6.8)}$$

where $\mathbf{m_s}$ and $\mathbf{m_a}$ are defined above. Placing expressions (D.6.7) and (D.6.8) into formula (D.6.5) yields the basic PAM formula:

$$N = \frac{N_r + N_p}{1 - \frac{m_a}{60} - \frac{m_s}{60}} \qquad \text{(D.6.9)}$$

APPENDIX D.7: Average Total Number of On-Duty Troopers ($\mathbf{N_o}$) Required Per Day for All Patrol Activities Within the APA, Adjusted for One and Two Trooper Units, (6.2.4)

Determination of the total number of on-duty troopers required per day ($\mathbf{N_o}$) is based on:

- the average total number of patrol units needed per day ($\mathbf{N_u}$), and
- the percent of patrol units that are staffed with two troopers (**P2T%**).

The average total number of patrol units needed per day ($\mathbf{N_u}$) is equal to the average total number of on-duty troopers needed each day if every patrol unit is staffed with only one trooper. The number of on-duty troopers required per day is calculated in Step (6.1.5) of the PAM manual. (The derivation for the formula used in Step (6.1.5) is given in Section D.6 above.)

The percent of patrol units that are staffed with two troopers (**P2T%**) is entered by the user in Step (6.2.1). Based on **P2T%**, define

$$f = \frac{P2T\%}{100} \qquad \text{(D.7.1)}$$

where **f**, calculated in Step (6.2.2), represents the fraction of units staffed with two troopers. Using $\mathbf{N_u}$ and **f**, let

$$N_{2u} = f \times N_u \qquad \text{(D.7.2)}$$

where $\mathbf{N_{2u}}$ represents the number of patrol units per day that are staffed with two troopers. If $\mathbf{N_{1u}}$ represents the number of patrol units per day that are staffed with one trooper, then

$$N_u = N_{1u} + N_{2u} \qquad \text{(D.7.3)}$$

Solving (D.7.3) for $\mathbf{N_{1u}}$ and replacing $\mathbf{N_{2u}}$ with (D.7.2) yields

$$N_{1u} = N_u - N_{2u}$$

$$N_{1u} = N_u - (f \times N_u)$$

$$N_{1u} = (1 - f) \times N_u \qquad \text{(D.7.3)}$$

The total number of on-duty officers is given by

$$N_o = 1 \times N_{1u} + 2 \times N_{2u} \qquad \text{(D.7.4)}$$

Replacing $\mathbf{N_{1u}}$ with (D.7.3) and $\mathbf{N_{2u}}$ with (D.7.2) in (D.7.4) and rearranging yields:

$$N_o = 1 \times (1 - f) \times N_u + 2 \times (f \times N_u)$$

$$N_o = (1 + f) \times N_u. \qquad \text{(D.7.5)}$$

Formula (D.7.5) is used in Step (6.2.4).

Appendix D.8: Average Total Number of On-Duty Troopers ($\mathbf{N_{ot}}$) and On-Duty Field Supervisors ($\mathbf{N_{os}}$) Required Per Day for Patrol Activities Within the APA, Adjusted for the Presence of Field Supervisors and Special Assignment Personnel, (7.2.4) and (7.3.1)

Introduction

The adjusted number of on-duty troopers required per day ($\mathbf{N_{ot}}$) is based on the formula (7.2.4):

$$N_{ot} = K_f \times \left(N_o + N_{s1} \times f_{s1} + N_{s2} \times f_{s2} + N_{s3} \times f_{s3} \right) \quad \text{(D.8.1)}$$

where:

$$K_f = \frac{s}{s + f},$$

and

N_o - the unadjusted number of on-duty troopers required per day determined in Step (6.3.2);

s - the average span of control for field supervisors (i.e., the average number of troopers supervised by each field supervisor specified by the user in Step (1.2.3) and transferred to Step (7.1.1);

f - the fraction of supervisor on-duty time spent on patrol activities (i.e., non-supervisory activities); calculated in Step (7.1.3);

f_{s1}, f_{s2}, f_{s3} - the fraction of on-duty time troopers assigned to special units spend on non-patrol activities; calculated in steps (7.2.1.5), (7.2.2.5), and (7.2.3.5) for special assignments 1, 2, and 3 respectively; and

$\mathbf{N_{s1}}$, $\mathbf{N_{s2}}$, $\mathbf{N_{s3}}$ - the number of troopers assigned to special assignments 1, 2, and 3; user-supplied values entered in steps (7.2.1.2), (7.2.2.2), and (7.2.3.2) respectively.

The number of on-duty field supervisors required ($\mathbf{N_{os}}$) is given by:

$$N_{os} = \frac{N_{ot}}{s} \qquad \text{(D.8.2)}$$

which is determined in Step (7.3.1) of the Manual.

Derivation of the Formula for the Adjusted Number of On-Duty Troopers ($\mathbf{N_{ot}}$)

If the percent of field supervisor on-duty time ($\mathbf{F_{s\%}}$) spent on patrol activities is known, the fraction ($\mathbf{f}$) can be determined as:

$$f = \frac{F_{s\%}}{100} \qquad \text{(D.8.3)}$$

The percent $\mathbf{F_{s\%}}$ is specified by the user in PAM in (1.2.4) and transferred to (7.1.2). The calculation for (D.8.3) is Step (7.1.3) in the manual.

If the percents of on-duty time ($\mathbf{S_{\%1}}$, $\mathbf{S_{\%2}}$, and $\mathbf{S_{\%3}}$) that troopers assigned to special assignments 1, 2, and 3 respectively spend on patrol activities are known, the fractions ($\mathbf{f_{s1}}$, $\mathbf{f_{s2}}$, and $\mathbf{f_{s3}}$) can be determined as:

$$f_{s1} = \frac{100 - S_{\%1}}{100} \qquad \text{(D.8.4)}$$

$$f_{s2} = \frac{100 - S_{\%2}}{100} \text{ and} \qquad \text{(D.8.5)}$$

$$f_{s3} = \frac{100 - S_{\%3}}{100} \qquad \text{(D.8.6)}$$

The percents $S_{\%1}$, $S_{\%2}$ and $S_{\%3}$ are supplied by the user in steps (7.2.1.3), (7.2.2.3), and (7.2.3.3); and calculations for (D.8.4), (D.8.5), and (D.8.6) are completed in steps (7.2.1.5), (7.2.2.5), and (7.2.3.5) respectively.

The derivation of formula (D.8.1) depends on the observation that regardless of the values for s, $F_{s\%}$, N_{s1}, N_{s2}, N_{s3}, $S_{\%1}$, $S_{\%2}$, and $S_{\%3}$ provided by the user, the total number of "full-time equivalent" on-duty troopers required per day after adjusting for the presence of field supervisors and troopers assigned to special units must equal the number of unadjusted on-duty troopers required per day (N_o) determined in Worksheet 6; that is:

$$N_o = N_{aft} + f \times N_{os} + g_{s1} \times N_{s1} + g_{s2} \times N_{s2} + g_{s3} \times N_{s3} \qquad (D.8.7)$$

where:

- N_{aft} - represents the adjusted number of on-duty troopers <u>not</u> assigned to a special unit;
- $f \times N_{os}$ - represents the full-time equivalent number of troopers for patrol that will be provided by the presence of the N_{os} field supervisors;
- g_{s1}, g_{s2}, g_{s3} - represent the fraction of on-duty time troopers assigned to special units 1, 2, and 3 respectively spend on patrol activities
- $g_{s1} \times N_{s1}$ - represents the full-time equivalent number of troopers for patrol that will be provided by the presence of the N_{s1} troopers assigned to special assignment 1;
- $g_{s2} \times N_{s2}$ - represents the full-time equivalent number of troopers for patrol that will be provided by the presence of the N_{s2} troopers assigned to special assignment 2; and
- $g_{s3} \times N_{s3}$ - represents the full-time equivalent number of troopers for patrol that will be provided by the presence of the N_{s3} troopers assigned to special assignment 3.

Replacing $\mathbf{N_{os}}$ in (D.8.7) with formula (D.8.2) yields:

$$N_o = N_{aft} + f \times \overset{N_{ot}}{\underset{s}{)))))}} + g_{s1} \times N_{s1} + g_{s2} \times N_{s2} + g_{s3} \times N_{s3} \qquad \text{(D.8.8)}$$

The term $\mathbf{N_{ot}}$ can be expressed as:

$$N_{ot} = N_{aft} + N_{s1} + N_{s2} + N_{s3} \qquad \text{(D.8.9)}$$

Solving (D.8.9) for $\mathbf{N_{aft}}$ yields:

$$N_{aft} = N_{ot} - N_{s1} - N_{s2} - N_{s3} \; . \qquad \text{(D.8.10)}$$

Replacing $\mathbf{N_{aft}}$ in (D.8.8) with (D.8.10) and solving for $\mathbf{N_{ot}}$ yields:

$$N_{ot} = K_f \times N_o + N_{s1} \times (1-g_{s1}) + N_{s2} \times (1-g_{s2}) + N_{s3} \times (1-g_{s3}) \qquad \text{(D.8.11)}$$

where:

$$K_f = \overset{s}{\underset{s + f}{)))))))}}$$

Formula (D.8.11) can be further simplified by noting that

$$g_{s1} + f_{s1} = 1; \quad g_{s2} + f_{s2} = 1; \quad g_{s3} + f_{s3} = 1; \qquad \text{(D.8.12)}$$

which yields:

$$f_{s1} = g_{s1} - 1; \quad f_{s2} = g_{s2} - 1; \quad f_{s3} = g_{s3} - 1. \qquad \text{(D.8.13)}$$

Using the results of (D.8.13) in (D.8.11) yields formula (D.8.1):

$$N_{ot} = K_f \times \left(N_o + N_{s1} \times f_{s1} + N_{s2} \times f_{s2} + N_{s3} \times f_{s3} \right) \quad \text{(D.8.14)}$$

where:

$$K_f = \left(\frac{s}{s + f} \right)$$

The calculation of formula (D.8.14) in Worksheet 7 is completed in sections 7.1 and 7.2. The adjustment factor ($\mathbf{K_f}$) is calculated for Step (7.1.5). The term $K_f \times N_o$ is calculated in Step (7.1.6). The remaining factors in (D.8.13) are calculated in steps (7.2.1.-6), (7.2.2.6), and (7.2.3.6). The entire sum is produced for Step (7.2.4).

Notice that if no patrol work is done by field supervisors (i.e., if f = 0) and no special assignment personnel are used (i.e., if $N_{s1} = N_{s2} = N_{s3} = 0$), then $N_{ot} = N_o$).

APPENDIX D.9: Determination of the Shift Relief Factor (**SRF**) for the Calculation of the Total Number of Troopers ($\mathbf{N_t}$) and Field Supervisors ($\mathbf{N_s}$) Required Within the APA, (8.2.8), (8.3.1) and (8.3.2)

Introduction

The shift relief factor for a law enforcement agency is used to determine the total number of officers that must be available (i.e., both on- and off-duty) in order to support a specified average number of on-duty troopers each day. The shift relief factor is defined as "the average number of persons required to cover one shift position every day."

For agencies with 8-hour shifts, shift relief factors typically fall in the range of 1.60 to 1.90. A shift relief factor of 1.70 for an agency using 8-hour shifts would indicate that the total staff for regular duty should be approximately 1.7 times the average number of on-duty positions that the agency plans to use per day. As an example, in order to cover 10 positions a day, this agency would have to have a total of 10 x 1.7 = 17 troopers available. (With 8-hour shifts and one trooper per unit, three positions are needed every day to support one 24-hour coverage unit.)

Shift relief factors increase as the shift length increases. Agencies using 10-hour shift will have shift relief factors in the range: 2.00 to 2.40. Relief factors for agencies with 12-hour shifts are in the range: 2.40 to 2.90.

Derivation of the Shift Relief Factor for Patrol Duty

The shift relief factor is determined by the shift length, the average work week, the average amount of benefit time off given to each trooper, and the amount of time troopers spend on temporary special assignments. Calculation of the relief factor for an agency is usually based on data collected for one year and used in the following formula:

$$SRF = \frac{365 \times S_1}{\text{Average Number of On-Duty Hours on Patrol Per Trooper Per Year}} \quad \text{(D.9.1)}$$

where:

SRF - shift relief factor (number of troopers), and

S_1 - shift length (hours).

The expression 365 x S_1 in (D.9.1) indicates the number of hours required to cover one position every day for an entire year. This value is calculated in Step (8.2.2). The denominator in (D.9.2) is the average number of on-duty hours provided by each trooper in one year. This value is calculated in Step (8.2.7). Calculation of the shift relief factor is completed in Step (8.2.8). The total number of troopers and total number of field supervisors required is calculated in steps (8.3.1) and (8.3.2).

Determination of the Average Number of On-Duty Hours on Patrol Per Year Per Officer

One difficulty with the use of formula (D.9.1) is that few agencies actually keep track of hours worked. Rather, most personnel time-recording systems are designed to keep track of the amount of time off for each trooper (e.g., vacation, holiday, personal leave, etc.). Recognizing that, it is often easier to determine the shift relief factor for an agency if formula (D.9.1) is rewritten as:

$$SRF = \frac{365 \times S_1}{(365 \times S_1) - \text{Average Number of Non-Patrol Hours Per Year Per Trooper}} \quad \text{(D.9.2)}$$

In this form, the average number of on-duty hours per year per trooper is calculated as:

$$(365 \times S_1) - \text{Average Number of Non-Patrol Hours Per Year Per Trooper.} \quad \text{(D.9.3)}$$

The first term in (D.9.3) indicates the total number of hours that one trooper would be on-duty if he/she worked every day of the

year. The second term represents the average number of non-patrol hours per year per trooper. Subtracting one term from the other in (D.9.3) gives the average number of on-duty hours on patrol per year per trooper. The usefulness of formula (D.9.2) is that it requires information (i.e., average non-patrol time per trooper per year) that is maintained by most agencies.

The average number of non-patrol hours per year per trooper can be grouped into three categories:

- Regularly-scheduled time off. Unpaid time off each trooper receives based on the average work week used by the agency. As an example, a 40-hour work week provide each trooper with an average of two days off per week.

- Benefit time off. Paid time including vacation leave, holiday leave, personal time, and compensatory time. The different kinds of benefit time off given varies from agency to agency and from one part of the country to another.

- Temporary special assignments. On-duty time spent on non-patrol activities. For example, a trooper sent to a one-week training course in another state is obviously not available for patrol duty, but is considered "on duty" while at the training. Whether non-patrol, on-duty time should be included in the determination of the relief factor is not rigidly defined. An analyst trying to justify as many troopers as possible will likely not count non-patrol, on-duty time as on-duty patrol time in order to derive a higher relief factor. Another analyst, seeking to hold down staffing estimates, may decide to count all on-duty time whether spent on patrol or not to derive a lower value for the relief factor.

Formula (D.9.3) can be expressed as:

$$(365 \times S_1) - H_{rs} - H_b - H_{ta} \qquad \text{(D.9.4)}$$

where:

- H_{rs} - number of regularly-scheduled hours off per trooper per year,
- H_b - number of benefit hours off per trooper per year, and
- H_{ta} - number of on-duty hours spent on temporary special assignments (non-patrol) per trooper per year.

Note that the expression $(365 \times S_1) - H_{rs}$ equals the annual number of paid hours. Annual number of paid hours ($\mathbf{H_y}$) is also given by:

$$H_y = \frac{365 \times AWW}{7} \qquad \text{(D.9.5)}$$

where **AWW** represents the average work week in hours. Note that if AWW = 40, H_y is 2,085.7 hours per year. (The commonly used figure of 2,080 paid hours per year is based on exactly 52 weeks. Fifty-two weeks, however, equals only 364 days, one day less than the actual year.)

Replacing $(365 \times S_1) - H_{rs}$ in (D.9.4) with (D.9.5) yields:

$$\frac{365 \times AWW}{7} - H_b - H_{ta} \qquad \text{(D.9.6)}$$

which is calculated in Step (8.2.7). Using (D.9.6) as the denominator in (D.9.1) yields:

$$SRF = \frac{365 \times S_1}{\frac{365 \times AWW}{7} - H_b - H_{ta}} \qquad \text{(D.9.7)}$$

which is calculated in Step (8.2.8).

APPENDIX D.10: Allocation of Patrol Personnel Among Several APAs, Worksheet 9

Introduction

Worksheet 9 provides two methods for allocating a given number of staff among several APAs. Both methods rely on staffing estimates for each APA provided by the PAM model in worksheets 1 - 8. The first method, identified as "unconstrained allocation," indicates the ideal staffing if no limitations are imposed on how many troopers can be added or subtracted from the current staffing level in any APA (i.e., if there are no limitations on transfers between APAs). The second method, identified as "constrained allocation," can be used to determine the staffing allocation when a fixed number of additional troopers are to be added and no transfers of existing personnel are allowed. In this case, the no transfer constraint has the effect of insuring that no APA will lose staffing because of the allocation. The constrained allocation procedure can also be used to determine which APAs will lose personnel when staff reductions are required. In this case, the no transfer rule insures that no APA will gain personnel as a result of the overall staff reductions. All of the calculations for Worksheet 9 are summarized in Table 4-1.

The derivations below make use of the following notation:

- **T** - total number of staff in all of the APAs after the reallocation
- **TA** - total number of new staff (or total staff to be deleted)
- $\mathbf{TA}_i$ - total number of staff added to APA i (or staff deleted from APA i)
- **TC** - current total number of staff among all of the APAs
- $\mathbf{TC}_i$ - current number of staff in APA i
- **TE** - total number of staff estimated by the PAM model for all of the APAs
- $\mathbf{TE}_i$ - total number of staff estimated by the PAM model for APA i
- $\mathbf{T}_i$ - total number of staff in APA i after the reallocation

The total staff to be allocated is given by:

$$T = TC + TA \qquad \text{(D.10.1)}$$

Unconstrained Allocation

The rationale for the unconstrained allocation is that the total staff (**T**) should be distributed among the APAs in the same proportion as the PAM estimates; i.e.,

$$\frac{T_i}{T} = \frac{TE_i}{TE}, \quad \text{all APAs} \qquad \text{(D.10.2)}$$

Solving for $\mathbf{T_i}$ and replacing **T** with (D.10.1) yields the formula for the number of staff that should be assigned to each APA;

$$T_i = TE_i \times \frac{TA + TC}{TE} \qquad \text{(D.10.3)}$$

Constrained Allocation

The total staff to be allocated is given by (D.10.1) above. The difference ($\mathbf{d_i}$) for each APA between the number of staff provided by the unconstrained allocation for the APA (i.e, $\mathbf{T_i}$ given in (D.10.3)) and the number of staff estimated for the APA by the PAM model ($\mathbf{TE_i}$)is given by:

$$d_i = T_i - TE_i \qquad \text{(D.10.4)}$$

Expression (D.10.4) indicates whether an APA is under or overstaffed; i.e.,

if $d_i > 0$, the APA is overstaffed,

if $d_i < 0$, the APA is understaffed.

The $\mathbf{d_i}$ values are used to identify which APAs should gain staff (if TA > 0) and which APAs should lose staff (if TA < 0).

Additional staff (TA > 0). If staff is to be added to the APAs, the no transfer rule can be satisfied by distributing the new staff

only among those APAs that are understaffed (i.e., APAs with di < 0). Let **U** represent the collection of APAs that are understaffed and determine the total deficit staffing (**TN**) for these APAs by summing the $\mathbf{d_i}$s in **U**; i.e.,

$$TN = d_1 + d_2 + d_3 + \ldots + d_n \qquad \text{(D.10.5)}$$

-- only use APAs for which $d_i < 0$ --

Allocation of the **TA** staff among the APAs in **U** is given by (D.10.6) below where $\mathbf{TA_i}$ represents the number of staff added to APA i:

$$TA_i = d_i \times \left(\frac{TA}{TN}\right) \qquad \text{(D.10.6)}$$

The final allocation among all of the APAs is given by:

$$T_i = \begin{cases} TC_i & \text{if } d_i \geq 0 \\ TC_i + TA_i & \text{if } d_i < 0 \end{cases} \qquad \text{(D.10.7)}$$

Staff reduction (TA < 0). For staff reductions, the constrained allocation procedure uses the $\mathbf{d_i}$ values to identify those APAs that are overstaffed and, as a result, are eligible for staff reductions. Let **O** represent the collection of APAs that are overstaffed and determine the total surplus staffing (**TN**) for these APAs by summing the $\mathbf{d_i}$s in **O**; i.e.,

$$TN = d_1 + d_2 + d_3 + \ldots + d_n \qquad \text{(D.10.8)}$$

-- only use APAs for which $d_i > 0$ --

Allocation of the **TA** staff among the APAs in **O** is given by (D.10.9) below where $\mathbf{TA_i}$ represents the number of staff to be taken from APA i:

$$TA_i = d_i \times \left(\frac{TA}{TN}\right) \qquad \text{(D.10.9)}$$

Each $\mathbf{TA}_i$ value for staff reductions will be a negative number. The final allocation among all of the APAs is given by:

$$T_i = \begin{cases} TC_i & \text{if } d_i \leq 0 \\ TC_i + TA_i & \text{if } d_i > 0 \end{cases} \qquad \text{(D.10.10)}$$