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COUNTYWIDE **P**OLICE **S**IMULATION SYSTEM
COPS

Craig J. McDonald

**Rochester Institute of Technology
School of Computer Science and Technology**

COUNTYwide Police Simulation System

COPS

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**A Thesis, Submitted To
The Faculty of the School of Computer Science and Technology,
In Partial Fulfillment of the Requirements for the Degree of
Master of Science in Computer Systems Management**

Approved by: _____

Dr. Walter A. Wolf, Chair

Dr. Peter G. Anderson

Professor Jeffrey Lasky

September 1, 1987

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September 1, 1987

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COUNTYWIDE POLICE SIMULATION SYSTEM

ABSTRACT

COuntywide Police Simulation System (COPS) is a model which simulates the receipt of police, fire, and emergency medical calls at a public safety communications center, with subsequent dispatch of law enforcement officers to police events. The model examines the interaction of exogenous variables, including the type of call, the frequency of calls, the number of telecommunicators on duty, the number of police cars in service, the deployment pattern of the officers, the number of cars to be dispatched, and the dispatch plan.

By modifying the values that these variables can hold, the distribution of workload among police officers can be observed, response times and service times can be examined, and dispatching policies can be evaluated. Sensitivity analysis can be performed without disrupting the life-critical nature of the live operation. An interactive component permits the model to also be used as a training tool for police dispatchers.

The thesis presents reasons why it is important to gain a better understanding of the delivery of police services. Major considerations in developing a model are explored, especially as they relate to the simulation of police activity. Programs which gather data on event generation times, telecommunicator service times, patrol-unit travel and service times, event waiting times, and the number of cars per call are detailed.

A major portion of the thesis examines each module and entity used in the GPSS/H implementation of the simulation model. The important issue of validation is also addressed. Validation strategy, validation programs, and the construction of a "benchmark" are discussed. An evaluation of the success of the project is presented, with suggested areas for consideration and future research.

ACM's *Computing Reviews* Classification System

I. Computing Methodologies
 I.6 Simulation and Modeling
 I.6.3 Applications

H. Information Systems
 H.1 Models and Principles
 H.1.0 General

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SECTION 1

INTRODUCTION

This project uses computer simulation techniques to model the response of police patrol units to requests-for-service. The **Countywide Police Simulation model (COPS)** models the behavior of a police communications system and the delivery of police services to the community.

Simulation is the process of developing and executing a dynamic representation, or model, of a process or activity. Given a set of system characteristics, the model imitates the behavior of the process or activity. By modifying these characteristics, the model can provide alternative results. The results can then be compared for the purpose of selecting the combination of resources which seem to yield the most productive output for the system under study.

The delivery of police services involves the processing of an event, or call-for-service, from the moment that the call is received at an emergency communications center through disposition of the call by police officers. This process involves telecommunicators, dispatchers, and police officers.

From the telecommunicator perspective, it includes the receipt of a request for police service at a public safety communications center, the assignment of the call to an available telecommunicator, the interview of the calling party by the telecommunicator, and the transfer of the event information to a police dispatcher. The dispatcher is then responsible for selecting the most appropriate police unit(s) for dispatch. The police officer must travel to the scene, service the complainant, clear from the call, and return to preventive patrol.

The thesis was developed using the Monroe County, New York Sheriff's Department as the subject of the study. One shift of one zone was modelled. Although it is the goal of a simulation model to derive inferences about a system by examining its model, it is critical to note that this thesis is not intended to be used for the purpose of recommending changes in dispatch and/or patrol procedures for the Monroe County Sheriff's Department or any other law enforcement agency. Although this project offers several insights into police patrol activity, it must be subjected to extensive validation studies before leaving the academic realm.

Sections 2 through 10 provide detail to the summary set forth above.

Section 2 discusses the **police response**. Reasons why it is important to gain a better understanding of the "police response" are provided. The delivery of police services is also described.

Section 3, titled **modelling the police response**, explores major considerations in model development, especially as they apply to the delivery of police services.

Section 4 addresses **data collection**. Programs which determine event generation times, telecommunicator service times, police travel and service times, event waiting times, and number of cars per call are detailed.

Section 5 provides an examination of the **COPS model**. Entity definitions and module descriptions are provided to permit a complete understanding of the simulation process.

Section 6 presents **simulation results**. Sample output is included, as well as an explanation of its value. Many tables are provided, including patrol unit activity, pre-dispatch time, response time, service time, preventive patrol, unit assignment, and dispatch plan tables. Two graphs are also displayed: the number of calls handled by district units and the average waiting time within districts.

Section 7 addresses issues associated with **validation**. Validation strategy, validation programs, and the construction of a "benchmark" are discussed.

Section 8 is devoted to **conclusions**. An evaluation of the success of the project, from operational and training perspectives, is provided, as well as suggestions for future consideration and research.

Several appendices are included. Appendix A presents the results of the data collection effort, Appendix B shows sample output from the model, Appendix C includes the tables produced by the benchmark evaluation programs, and Appendix D displays several block diagrams.

SECTION 2

THE POLICE RESPONSE

2.1 THE VALUE OF UNDERSTANDING POLICE RESPONSE TIME

The subject of police response time (the time between a request for police service and the arrival of a police officer) is considered an important topic to study and to simulate because of its perceived impact by law enforcement officers on the quality of public safety services. This is true for several reasons.

There is believed to be an inverse relationship between response time and the apprehension rate of criminals.¹ The greater the delay in police response, the lower the probability of arrest. If response time could be lowered, so could the level of crime, because of the increased likelihood of arrest and conviction. There would be fewer repeat crimes by the same individual, and the deterrent effect of swift apprehension would be strengthened.

Similar to the preceding discussion, there is a strong relationship between low response time and the prevention of injury and loss. A fire multiplies rapidly. A time span of only a few minutes can mean the difference between life and death in a medical emergency. An assault may escalate into a rape within a matter of seconds. If response time could be decreased, the seriousness of personal injuries and property damage could be reduced.

There is also a correlation between low response time and the availability of police officers to conduct preventive patrol. If response time could be minimized, police officers could realize a savings in the time spent travelling to calls-for-service. This time could be dedicated to routine patrol or directed-deterrent patrol. To the extent that there is a relationship between preventive patrol and crime deterrence, the incidence of crime could be reduced. Furthermore, as more time is spent on service relationships with the community, a positive police-community attitude could be fostered.

Less dramatic, but no less important, is the association between response time and the equalization of workload among police officers. In order to reduce response time, patrol districts must be configured and staffed in such a fashion that calls require a minimum of "cross-district dispatch" of officers. By optimizing police patrol boundaries, calls-for-service would be more equitably assigned. This balancing of workload would promote positive feelings of equality among police officers by relieving one cause of job stress.

A study of response time is important for reasons other than the ability to identify factors which minimize time associated with police response. A recent study has documented a relationship between response time expectations and community satisfaction with police services.² Specifically, the study found that callers who are provided with a reasonable expectation of police arrival tend to be satisfied if their expectations are fulfilled. If response times could be accurately

estimated, police communications personnel could provide callers with a realistic understanding of the process. By establishing reasonable expectations, there would be a lower probability that calls for police service would escalate in severity because of negative feelings engendered through the call-for-service process.

Lastly, in light of the growing vulnerability of municipalities to liability claims, the ability to respond to the public in the most efficient and effective manner cannot be considered a future goal. If present police resources are not allocated in an optimal way, loss of life or property may bring about a large-scale law suit.

2.2 THE SCOPE OF THE STUDY

In order to appreciate the structure of the proposed model, an understanding of the environment which the system attempts to model is important. The police response can be divided into two areas: (1) the processing of calls-for-service by an emergency communications center, and (2) the actual delivery of police service.

The study was carried out in Monroe County, New York. Monroe County consists of nineteen towns and the City of Rochester, an area encompassing 673 square miles and a population of 702,238.³ Currently, thirteen law enforcement agencies provide police service to Monroe County. The largest suburban agency, the Monroe County Sheriff's Department (MCSD), is responsible for police service throughout Monroe County, but actively patrols those areas which are not served by a village, town, or city police department.

2.2.1 THE ENVIRONMENT OF THE COMMUNICATIONS CENTER

Sheriff's Deputies receive their calls from the Monroe County 911 Center. Individuals who call the Sheriff's Department directly, or call 911, are connected to the 911 Center. When a call is received at the 911 Center, an automatic call distribution (ACD) system routes the call to the telecommunicator (911 operator) who has been available the longest amount of time. The 911 telecommunicator interviews the calling party, verifies the address where assistance is requested, and extracts specific information, i.e., nature of call, description of the incident, caller's name, and address.

This information is entered into a computer-aided dispatch (CAD) system by the 911 telecommunicator. CAD routes the call to the dispatcher serving the police district where service is needed. CAD also recommends the units which should respond to the call, based on location of the call and availability of units. The dispatcher then selects the units which he/she intends to dispatch, broadcasts the message to the appropriate unit(s), and records in CAD the dispatch, arrival, and clearance of the unit(s) to the call-for-service.

2.2.2 THE ENVIRONMENT OF THE MONROE COUNTY SHERIFF'S DEPARTMENT

The Sheriff's Department is divided into three zones. Zone A covers the eastern end of Monroe County, an area which is primarily residential. Zone B includes the southern end of the County and has a rural, suburban, and light industrial mix. Zone C covers the western part of the County and includes a large rural area.

This study focuses on Zone B and its six districts. Specifically, this study concentrates on the 2 PM to 10 PM shift and the activities which occur during that period of time in Zone B.

Twelve police units typically patrol the territory included in Zone B, as follows:

District 1: 2 cars

District 2: 2 cars

District 3: 3 cars

District 4: 1 car

District 5: 1 car

District 6: 1 car

Floater and Supervisors: 2 cars

Multiple cars are assigned to a single district in an attempt to equalize workload and minimize response time without restructuring district boundaries.

Each car is staffed by one Sheriff's Deputy. The unit or units which are assigned to a specific district are assigned calls which originate in the district, if the unit is available. Units are dispatched from an adjoining district or zone if a district car is not available to respond. When not dispatched to a call, Deputies are expected to patrol the area included in their "home" district.

SECTION 3

MODELLING THE POLICE RESPONSE

This section presents a discussion of the simulation process. Several topics are presented: an introduction to simulation, the complexities and limitations associated with simulation, the selection of a simulation language, the application of simulation to the study of dispatch and patrol operations, and the use of simulation results.

3.1 INTRODUCTION TO SIMULATION

Simulation is the process of developing and executing a *model* of a specific *system*. Once the model has successfully passed the *validation process*, the system's behavior can be inferred from the behavior of the model itself. Several key terms must be defined.

A *system* is a process or activity, e.g. the receipt of a request for police service and the corresponding dispatch of one or more police units. In the COPS model, there are several key characteristics of the system:

- receipt of a call-for-service by the 911 Center;
- selection of the appropriate telecommunicator by the ACD;
- interview of the calling party by the telecommunicator;
- selection of the appropriate patrol unit by the dispatcher;
- dispatch of the patrol unit by the dispatcher;
- travel of the police car to the scene;
- service of the caller by the patrol officer; and
- return of the patrol unit to its home district.

A *computer model* is a program which attempts to represent the interaction of the key characteristics, such as those outlined above. In actuality, the modelling process includes a series of programs which gather the input data, execute the model, and validate the results.

The *validation process* refers to the degree to which the model reflects the behavior of the system. It is an indicator of the model's precision in forecasting the response of the system to external stimulants. These stimulants are exogenous variables which are described later in this section.

In the COPS model, the police communications and response process is the system of interest. Once the model is validated, an analyst could determine the response of a public safety communications center and a police agency to requests for law enforcement assistance.

3.2 SIMULATION CONSIDERATIONS

The ease with which an analyst can embark on the path of simulation requires that an understanding of its strengths and weaknesses be fully comprehended. Section 3.2 summarizes many of the excellent points discussed by Bobillier et al. in Simulation with GPSS and GPSS V.⁴

Like the design of any major computer system, the tasks of systems analysis and programming must be brought together. In the case of simulation, two areas require special attention: debugging and validation.

3.2.1 Debugging a simulation model is more difficult than debugging a "typical" computer program, because of the simultaneous nature of "events" moving through the model. In a typical program, a record (unit of work) often flows sequentially from one module to the next. In a simulation model, however, multiple event transactions (units of work) are simultaneously processed at different stages of the system. During the execution of the model, event transactions can be stalled at a module while newer transactions "speed" around the blockage. The simulation language GPSS, General Purpose Simulation System, employs current and future events chains which are constantly scanned to determine the next transaction which can move through the system. This dynamic, and often simultaneous, process complicates the task of debugging a model.

3.2.2 Validation also deserves special consideration. First, validation is an expensive undertaking. In order to gain a high degree of confidence in the ability of a model to reflect the behavior of a system, many computer runs must be initiated. The level of confidence in the accuracy of the various alternatives under study is directly proportional to the number and length of the computer runs.

Secondly, validation is an intricate process. The nature of random variables used in the model do not enhance one's confidence in the precision of the results. Furthermore, the accuracy of the input data is critical to the validation effort. If the sampling error is large, validation of the model will be difficult to achieve. If the data upon which the simulation depends is insufficient in properly describing the characteristics of the system, validation will suffer.

3.2.3 In addition to debugging and validation considerations, the **limitations** of simulation must always be kept in mind. A simulation model does not recommend optimum strategies or definite courses of action. Rather, it provides a framework for identifying possible areas for detailed analysis. Simulation narrows the scope of promising alternatives; however, it does not identify the best choice. As such, the cost of designing, programming, debugging, and validating a model must be weighed against the expected utility of the results.

For these reasons, the decision to simulate must be a decision based on careful analysis of the alternatives. If the behavior of a system can be predicted by using a mathematical formula, then simulation is an expensive undertaking which would not prove cost effective. However, if the system's characteristics cannot be definitively described by mathematics, or the system exhibits

random fluctuation in its responses, then simulation is appropriate.

The preceding discussion is meant to temper a quick decision to create a model. The ease with which a simulation model can be developed may lead the programmer into a false sense of confidence in believing that the model accurately and completely replicates the system under study. The assumptions upon which the model is based must always be kept in mind. If not, it is possible that the analyst could fall into the trap of generalizing results beyond the scope of the simulation run.

3.2.4 After embarking on the design of a model, the analyst must determine the **programming language** that the model will employ. A simulation model can be programmed using a conventional high-level language, such as Pascal or C. However, by undertaking this effort, the analyst must distribute his/her time between the administrative details of modelling and the functional aspects of modelling.

It is preferable, therefore, to use an established simulation programming language for model development. A simulation language permits the analyst to focus on the development of the model itself by providing an event sequencer, a system clock which records simulated time, random number generation, statistical data collection, and model initialization and debugging services.

GPSS/H, or General Purpose Simulation System, is one such language. GPSS/H contains the core requirements of a simulation language which are listed above. In addition, it is relatively easy to learn and straightforward in its application. Program coding follows the same concepts as problem analysis. The interactive debugger, compile and run time diagnostics, interactive input and output features, report generation capabilities, and vendor support make GPSS/H a valuable programming language.

3.3 APPLYING SIMULATION TO "THE POLICE RESPONSE"

3.3.1 INTRODUCTION

Simulation does, in fact, possess advantages for the decision-making process. In the case of the delivery of police services, where mathematical formulas fall short of describing the interaction of complex system variables, simulation seems most appropriate.

A cost-benefit analysis also favors simulation, even with the caveats expressed about debugging and validation. In a law enforcement environment, as in the private sector, the combination of limited financial resources, increased concerns over liability, and added emphasis on productivity and time optimization demand that new ideas be based on a sound foundation. If a new approach is not the product of careful research, adverse effects could be produced. Expending the time to debug and validate a model may be less costly than modifying live resources.

For example, a new dispatch procedure could result in a delay in the delivery of police services and, therefore, create the opportunity of dire consequences to life and property. The addition of manpower is a costly venture, given the amount of training which a new police recruit must accomplish. The reassignment of existing police officers may create liability exposure in those areas which are deprived of personnel. In sum, the life-critical nature of policing demands that system interference be kept to a minimum. Experimenting with the "live" system is costly, time consuming, and potentially dangerous.

For these reasons, police managers, police planners, municipal budget analysts, and legislative researchers could benefit from the use of simulation. After design of a flexible model, these individuals could examine the behavior of the system by modifying input variables. Operational audits would be facilitated by comparing actual operations with the behavior of a model. Deviations could then be focused on by an audit team to determine if the actual system is truly deficient. The quality of budget preparation and review efforts would also be improved if the relationship between external system variables (calls-for-service; community demands for quick police response time) and resource requirements (number of personnel) were examined in a systematic manner.

3.3.2 REPLICATING SYSTEM CHARACTERISTICS

Simulation models replicate the interaction of system variables. Variables which reflect the external behavior of the actual system are called exogenous variables. Variables which depend on the dynamics of the model are called endogenous variables.

Four categories of exogenous variables can be identified in the COPS model, including call-for-service variables, communications center variables, dispatch policy variables, and police patrol variables.

Endogenous variables in the COPS model are the event flow from the telecommunicators to the dispatcher, patrol unit dispatch time, patrol unit arrival time, and patrol unit clearance time. Workload of telecommunicators and patrol units is also a function of model dynamics.

In regard to *calls-for-service*, the user may determine the interarrival times of events requiring police response. The number of calls which are processed in a given shift can therefore be controlled. For each call, the analyst may also determine the location and type of the event, as well as its priority.

The user may also determine the number of telecommunicators which staff the *communications center*. The combination of call frequency, call type, and the number of telecommunicators has an effect on the number of calls that a telecommunicator can process and, consequently, on the idle time of the telecommunicators. If call-for-service volume is low, and/or there is a large number of telecommunicators on duty, the number of calls per telecommunicator

will tend to be fewer than normal, and telecommunicators will experience more free time. The model can assume different values for each of the exogenous variables, thereby affecting the workload of the telecommunicators.

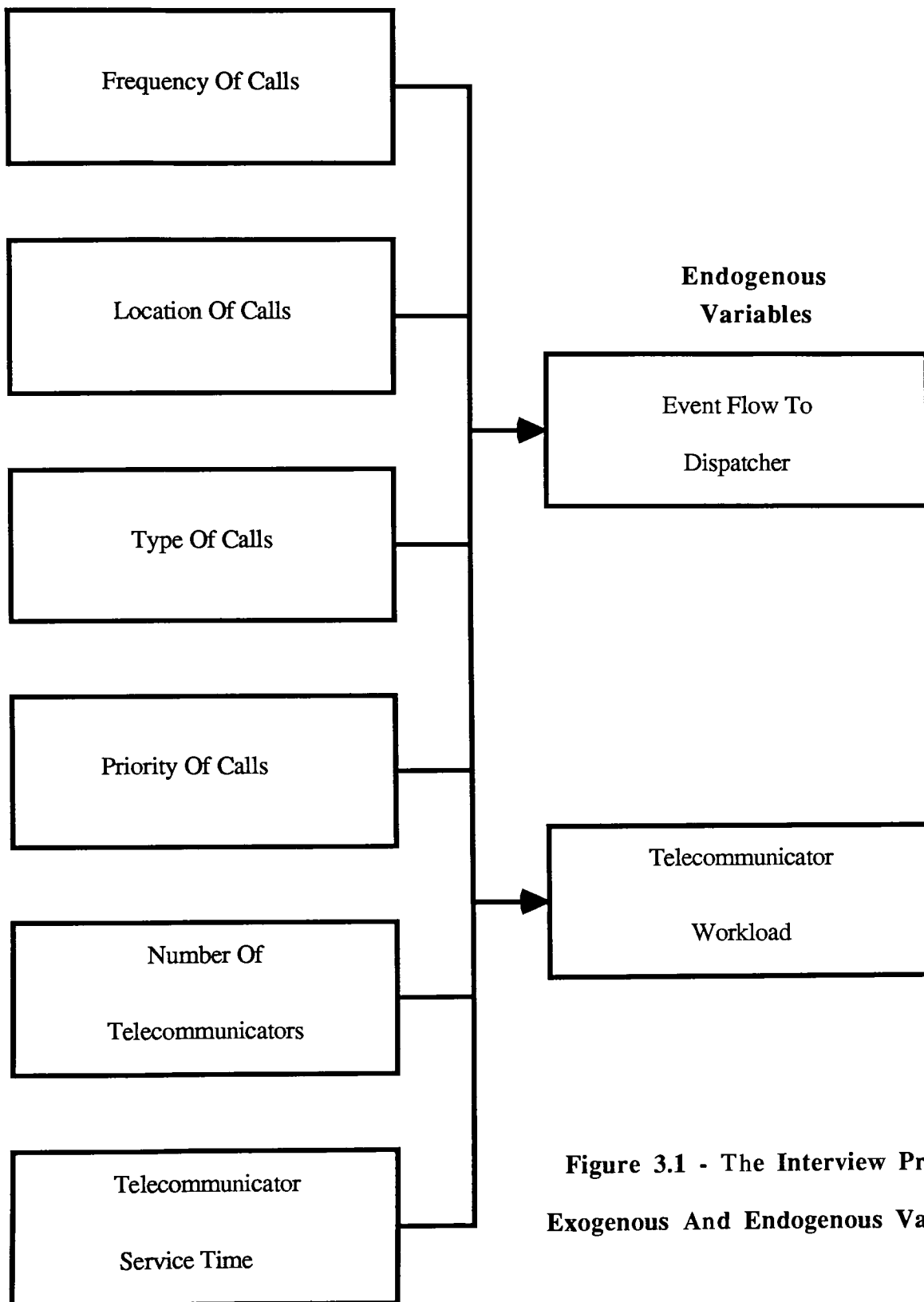
The next stage of the model, the dispatch of the appropriate police response, depends on certain exogenous inputs, as well as the results of the telecommunicator phase. Specifically, the *dispatch policy* variables of dispatch plan and dispatch instructions combine with the flow of events leaving the telecommunicators to create an external system input for the dispatcher. The dispatch instructions for a specific type of call are dependent on the priority of the call and the method by which it was reported, while the dispatch plan is a factor of the origin of the call. These variables determine the number of cars required for a specific call, and the districts from which they should be selected, respectively. The amount of time that an event waits at the dispatcher's workstation before dispatch of a unit is also within the dispatch policy category.

Exogenous variables of the *police patrol* type include the total number of police cars in the zone, the district assignments of the vehicles, patrol unit travel time, and patrol unit service time. The synthesis of these variables contributes to the final selection of police units, and the dispatch, arrival, and clearance times associated with a particular call-for-service.

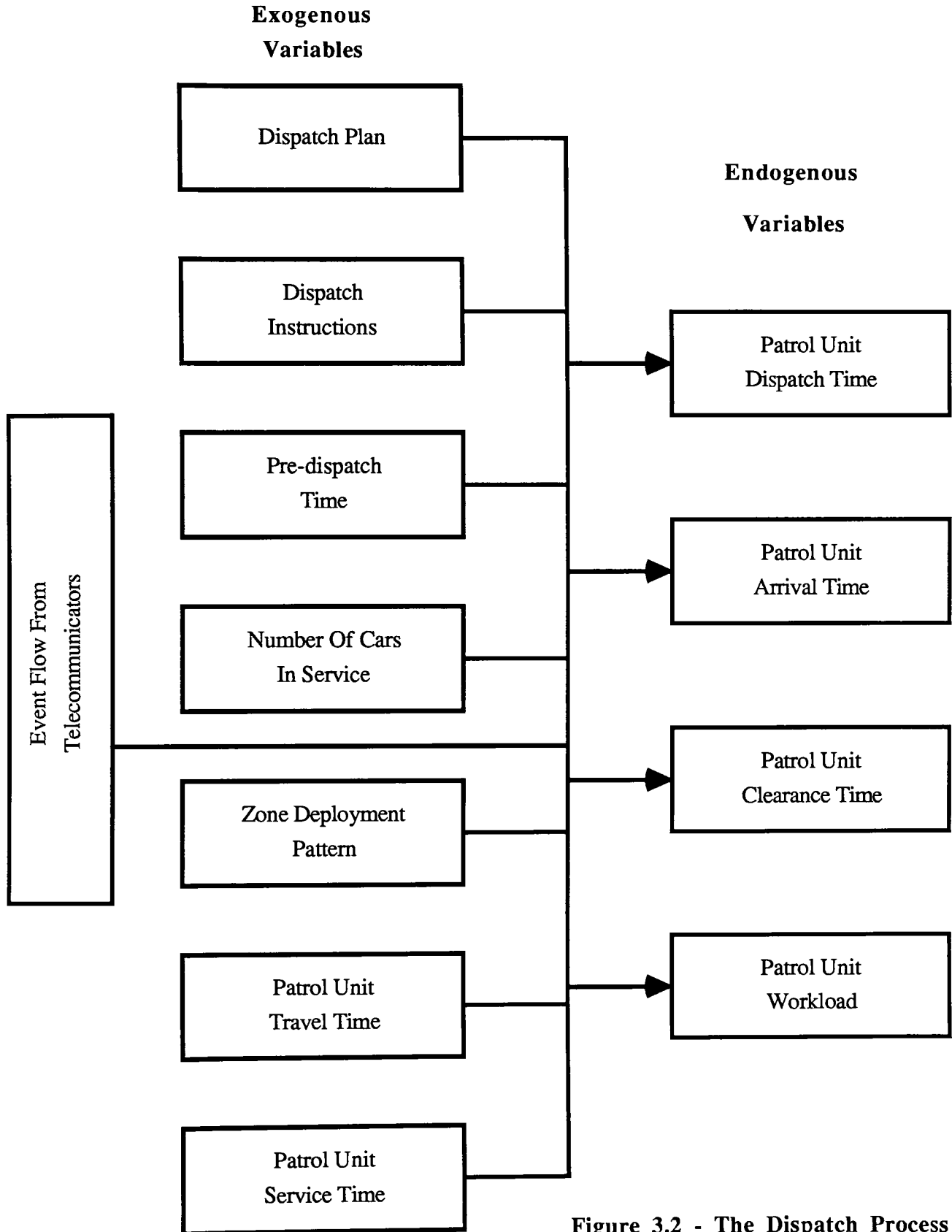
Figures 3.1 and 3.2 illustrate the interaction of the exogenous and endogenous variables of the COPS model.

By examining both telecommunicator service time and patrol unit travel time, the length of time that elapses between a caller's request for assistance and the arrival of police units can be determined. Furthermore, police idle time is calculated by the model. This period of availability translates into preventive patrol time. Thus, the model provides insight beyond the subject of police response time. By examining the frequency and location of preventive patrol vis a vis criminal activity, better strategies can be coherently developed.

Exogenous Variables



**Figure 3.1 - The Interview Process
Exogenous And Endogenous Variables**



**Figure 3.2 - The Dispatch Process
Exogenous And Endogenous Variables**

3.3.3 MODEL OUTPUT

The modelling process allows "what if" questions to be answered. An evaluation of police service can be assisted by answering such questions under a variety of operating conditions. An illustrative list of such questions follows:

- (1) How long do individuals have to wait for a call to be answered?
- (2) After completion of a call, how long do individuals have to wait for a police car to arrive?
- (3) How busy are telecommunicators?
- (4) How busy are police officers?
- (5) What impact on waiting time and workload would occur if:
 - fire calls increased by 10%?
 - cars did not cross district boundaries to answer calls?
 - additional cars were added to certain districts?
- (6) What are the travel times of patrol units for each district?
- (7) What are the event delays for each district?
- (8) How many calls does each unit respond to in its primary district and in adjoining districts?
- (9) How much time does each unit spend:
 - in conducting preventive patrol?
 - in servicing calls?
- (10) What operational changes would be observed if calls were assigned different priorities?
- (11) What effect would be felt by the community and by police units if certain calls were not to receive a police response?

SECTION 4

DATA COLLECTION

The COPS model requires information from the live system to determine the rate of event generation and to build functions. In order to collect this data, programs were developed on the computer-aided dispatch system to analyze system characteristics.

Section 4 describes programs which (1) capture event data; (2) determine the number of cars which are dispatched to events; and (3) calculate patrol unit travel and service times, telecommunicator interview and event entry times, and event waiting times. On the following pages, the logic of the data collection programs is presented and, where appropriate, a description of individual modules is provided.

4.1 CALLS-FOR-SERVICE

The COPS model can operate with probabilistic or historical event generation routines. Three programs will be presented to explain the method of collecting this data. The first program, **HISTORICAL EVENT GENERATION**, is used to capture actual event and unit information on each call-for-service for a specified shift. The second program, **PROBABILISTIC EVENT GENERATION**, is used to determine the interarrival means associated with four types of calls: police central-dispatch, police agency-transfer, fire, and emergency medical services. The third program, **SHERIFF'S EVENT DATA**, analyzes events which are handled by the Monroe County Sheriff's Department. Appendix A includes output from these data collection programs.

4.1.1 PROGRAM - HISTORICAL EVENT GENERATION

The MAIN module of this program identifies events which occurred between 2 PM and 10 PM in Zone B of the Monroe County Sheriff's Department. It also writes the location of each selected call to file ADDRESS, and the event type of each selected call to file CALLS.

Two files were used to record location and call-type data, rather than a two-field record within one file, because of data-transfer constraints. Input data was transferred from the computer-aided dispatch system to a personal computer, which then relayed the data to the RIT computer on which the model ran. Line-length restrictions of the personal computer prevented the use of a two-field record. Assuming no such line-length limitations, one file should be used.

The MAIN module also calls Procedures PRINT UNIT, PRINT EVENT, and GPSS PRINT. Procedure PRINT EVENT records event number, time of call receipt, district of call origination, call priority, and the number of cars assigned to the call. Procedure PRINT UNIT records unit characteristics for the event, including unit number, unit district, pre-dispatch time, service time, onsite status, and action code for each patrol car dispatched to the event.

Procedures PRINT EVENT and PRINT UNIT also print the data set forth above in a report for use by the analyst in comparing the input data to the results printed in the EVENT LOG MODULE of the model. This comparison would be performed to verify the correct sequencing of unit transactions under the historical mode.

Procedure GPSS PRINT records the data in a file for direct use by the model COPS.

4.1.2 PROGRAM - PROBABILISTIC EVENT GENERATION

The COPS model generates an event stream which is representative of all calls received at the Monroe County 911 Center. In order to determine the characteristics of this flow, a data collection program was written to analyze the types of calls received at the Center. After analyzing each call-for-service, an interarrival mean is calculated.

The MAIN module selects calls which were received from 2 PM to 10 PM by telecommunicators. Each call is classified as one of four types.

A police central-dispatch call is one in which the event will be transferred to a dispatcher at the 911 Center. Sheriff's calls are a subset of this group and are handled separately. A police agency-transfer call is one which the telecommunicator transfers to a local police agency. Fire calls comprise the third group, while emergency medical services (ambulance) calls belong to the fourth category.

Interarrival means for the four types are determined in Procedure PRINT REPORT by calculating an average hourly rate, and then dividing this number into 3600 (the number of seconds in an hour). The result is the number of seconds between calls for each type.

4.1.3 SHERIFF'S EVENT GENERATION

Analyzing Sheriff's event data requires two programs. The first program, EVENT EXTRACT, selects four fields of data from the master event data record. The master event data record includes event and patrol unit information which has been extracted from the computer-aided dispatch system. A file of these records is used as input to several data collection programs for additional data extraction and processing.

The second program, EVENT ANALYSIS, accepts records which have been sorted on district, priority, onsite status, and time of event creation. This program performs the analysis of the records, and produces formatted output with interarrival times. A description of EVENT EXTRACT and EVENT ANALYSIS follows:

4.1.3.1 PROGRAM - EVENT EXTRACT

The MAIN module extracts all Monroe County Sheriff's Department (MCSD) events where the creation time is greater than or equal to 2 PM and less than or equal to 10 PM, and the primary responding unit is assigned to Zone B. If the district of call origination is available, then the district is assigned to the output record. Otherwise, the unit's district is assigned as the district of call origination.

The assumption stated above must be kept in mind as a potential weakness of the data collection effort. When a location is verified by a telecommunicator or dispatcher, the CAD system assigns a unique location identifier to the event. In some cases, CAD verification does not occur. This could happen if the telecommunicator entered an address which is not in the CAD street database. Most likely, however, the dispatcher created an onsite event for a patrol unit and failed to provide sufficient detail to allow CAD to confirm the address. Onsite events are most often created in a unit's home district.

4.1.3.2 PROGRAM - EVENT DATA ANALYSIS

The MAIN module accepts sorted records from EVENT EXTRACT and compares the district, priority, and generation-status fields. Matching records are tallied. The program then calls the module CALCULATE.

Procedure CALCULATE determines the interarrival time for a collection of calls-for-service which share the same district, priority, and onsite status. The interarrival mean time is calculated by dividing the total number of calls by the number of hours for which data was collected. This figure is then divided into 3600 (the number of seconds in an hour) to determine the number of seconds between calls-for-service. The logic of Procedure CALCULATE is based on the Poisson and exponential probability distributions. Statistical theory notes that:⁵

If the occurrences are generated by a Poisson process . . . , the lengths of time between successive occurrences are statistically independent random variables from an exponential distribution.

. . . if the mean number of occurrences per time interval is $[\lambda]$ (the Poisson parameter), the mean length of time between successive occurrences is $1/[\lambda]$.

For example, the number of calls-for-service within an hour period is described by a Poisson distribution, with mean = $\lambda = 85$ calls per 60 minutes ($85 \div 60 = 1.42$). The lengths of time between calls-for-service are described by an exponential distribution, with mean = $1 \div \lambda = 1 \div 1.42 = .7$ of a minute. Therefore, calls will arrive exponentially around a mean of 42 seconds ($.7 * 60$ seconds).

Procedure CALCULATE employs this logic with the simplified expression $(3600 \div (\text{number of calls} \div \text{number of hours}))$. Repeating the example listed above, Procedure CALCULATE would determine the interarrival mean as follows: $3600 \div (85 \div 1) = 3600 \div 85 = 42.35$ seconds.

4.2 UNITS PER EVENT

Upon receipt of an event from a telecommunicator, the dispatcher is advised by the computer-aided dispatch system of the number of units which should be dispatched. This number is modified by the dispatcher, depending on available information, such as the seriousness of the call. Two programs analyze this scenario. Program DATA SELECTION calculates the number of cars which are dispatched to events. Program NUMBER OF CARS constructs a frequency distribution of the number of units which have been dispatched, given the priority of calls and their source, i.e. officer or citizen. Appendix A displays a sample frequency distribution.

4.2.1 PROGRAM - DATA SELECTION

The MAIN module selects events from the master event data file which have occurred between 2 pm and 10 pm. It then classifies the events, by priority, as officer-generated or citizen-generated. MAIN then calls RECORD DATA to total the number of vehicles which responded to the event.

There is a weakness with this data collection program. The number of cars which are counted for each call-for-service is used to determine the number of Zone B units which should be dispatched. However, the program does not verify that all the vehicles are, in fact, assigned to Zone B. The intent of the program is to determine the absolute number of units required for a call. This information is used to determine the number of assisting officers which should accompany the primary unit.

In retrospect, two data collection programs should have been employed. The first program should just calculate the number of Zone B vehicles. This data would be used for purposes of model validation. The second program should calculate the absolute number of vehicles, regardless of their district origin. Functions would be created from this data to determine the number of units which are needed for a particular call-for-service during regular simulation runs.

4.2.2 PROGRAM - NUMBER OF CARS

Procedure RECORD CARS updates one of six variables which represents a cumulative count of the number of cars which were dispatched on an individual call-for-service. For example, if the current record shows that two cars were dispatched, the variable representing "two unit dispatches" would be incremented by one for a given generation status and call priority.

Procedure PRINT DATA prints the number of cases in which a given number of patrol units was dispatched for a specific generation source (officer or citizen) and call priority combination. The percentage of these cases to the total number of cases is also printed. Similarly, the cumulative total and percentage figures are calculated and displayed for the generation source/priority combination.

4.3 TRAVEL TIME

The COPS model uses a travel time module to calculate the amount of time which elapses from the point of dispatch to the point of arrival at the scene of a call-for-service. This time is a function of the district in which the call occurs, the home district of the responding vehicle, and the priority of the call. Analyzing travel time requires two programs. The first program, TIME CALCULATION, extracts the call district, unit location, priority of call, dispatch order of unit, travel time, and service time fields from the master data record. The second program, TRAVEL TIME ANALYSIS, examines a sorted collection of records and calculates the average response time for a given grouping of incident district, unit location, and priority of call.

A more detailed description of TIME CALCULATION and TRAVEL TIME ANALYSIS follows.

4.3.1 PROGRAM - TIME CALCULATION

For each master data record, the MAIN module extracts events which (1) occurred between 2 PM and 10 PM, and (2) were handled by units assigned to one of the six districts in Zone B. Each event record is converted to a number of unit records, corresponding to the number of units which were dispatched to the event. The master data record can hold information on the first six cars which have been dispatched to a call-for-service. The MAIN module may therefore call Procedure CALCULATE up to six times for a given master event data record.

Procedure CALCULATE determines the travel and service times for each unit assigned to an event. Travel, or response, time is the difference between unit arrival at the scene and dispatch of the unit. Service time is the difference between clearance of the call by a particular unit and its arrival at the scene.

A weakness of the data collection effort rests on the fact that the CAD system does not always contain a valid travel and service time for a patrol unit. This situation would occur if a dispatched unit failed to report his/her arrival to the dispatcher. Upon clearing from the call, the unit would only have a dispatch time and a clear time. If the unit does not report his/her arrival, neither travel time nor service time can be calculated. These cases are eliminated from further processing. Because these cases appear randomly, their exclusion does not bias the value of the travel and service time functions.

4.3.2 PROGRAM - TRAVEL TIME ANALYSIS

The MAIN module compares each record to the preceding record to determine if there are any changes in call district, call priority, or unit district.

If the values in each field of the current record are not changed, the cumulative travel time is increased by the amount of the current record's response-time field. However, if any of the fields change, the average travel time is calculated for a specified combination of the three variables listed above, and the table shown in Appendix A is printed.

4.4 SERVICE TIME

The COPS model calls upon a function to calculate the amount of time that a patrol unit spends servicing a call-for-service upon arrival at the scene. This time depends upon the priority (seriousness) of the event, as well as the "seniority" of the unit on the scene. In this context, seniority refers to the dispatch order of the vehicle, i.e. first, second, or third. The first unit to be dispatched is declared the primary unit. This unit takes control of the event and is the last car to leave the scene. This data collection program analyzes calls-for-service by determining an average service time for each unit, based upon the priority of the call, the dispatch order of the unit, and the district in which the call occurred.

Calculating service time requires two programs. The first program, TIME CALCULATION, has been described under the TRAVEL TIME section. The second program, SERVICE TIME ANALYSIS, analyzes the records and produces a table of values, with the following columns: incident district; unit dispatch order; call priority; average service time in seconds; and number of cases. Sample results are included in Appendix A.

4.4.1 PROGRAM - SERVICE TIME ANALYSIS

The MAIN program reads each record and compares it to the preceding record. If the district of call origination, call priority, and unit dispatch order are identical, then a cumulative service time variable is increased by the amount of the individual call's service time. If any of the record values mentioned above differ from those in the previous record, the program calculates the average service time, and then prints the incident district, unit dispatch order, call priority, average service time, and number of cases.

4.5 TELECOMMUNICATOR SERVICE TIME

The COPS model uses telecommunicator-service-time functions to determine the time associated with the interview of the calling party and associated entry of event data into the computer-aided dispatch system. Telecommunicator service time is a product of the type of call received at the 911 Center. Four types are possible.

The first type is a central-dispatch police call. These calls require a complete interview of the calling party, including location, type of call, suspect description, and follow-up phone number. Agency-transfer police calls receive an abbreviated interview from the telecommunicator. The location and type of the call are sufficient to permit transfer of the call to a remote dispatch point. Fire calls require a complete interview, although the amount of the information is not as extensive as is necessary in a central-dispatch police call. Lastly, emergency medical service (EMS) calls demand a quick, but thorough, interview.

Two programs perform the extract and analysis tasks which are necessary to develop the telecommunicator-service-time functions.

The first program, **TELECOMMUNICATOR SERVICE TIME DATA EXTRACT**, identifies the type of the call and the priority of the event. The length of the interview and associated CAD data entry is calculated by subtracting the time of call receipt from the time that the event was transferred to the dispatcher. The output record is then written to a file. This record contains the telecommunicator service time, hour of call receipt, type of call, and priority of the call. Only those events received between 2 PM and 10 PM are written to a file.

The second program, **TELECOMMUNICATOR SERVICE TIME ANALYSIS**, reads a sorted file of records produced by the first program. Procedure **RECORD DURATION** is called to update frequency distribution classes with the telecommunicator service time for the specific type of call, i.e. police central-dispatch, police agency-transfer, fire, or EMS. After all records have been tallied for a particular call type, Procedure **PRINT DATA** is called to print a six-column table. The call type, duration class, number of cases, percentage of total for each class, the cumulative total, and the cumulative percentage are calculated and written to a file. Furthermore, the GPSS function is also written on the report to facilitate transfer to the COPS model.

Appendix A displays telecommunicator service time data.

4.6 PRE-DISPATCH TIME

The COPS model uses pre-dispatch time functions to determine the time that the dispatcher waits before dispatching the next unit to an event. Pre-dispatch time is based on the percentage of patrol units available to the dispatcher, as well as the type of unit to be chosen, i.e. primary or assisting.

Three programs are required to build the GPSS pre-dispatch time functions. As a group, the programs develop a frequency distribution of the time between receipt of a call by a dispatcher and dispatch of each unit, given different levels of unit availability and unit type.

PRE_DISPATCH_TIME_1 extracts events to which a Sheriff's Zone B unit was dispatched as the primary unit between the hours of 2 pm and 10 pm.

PRE_DISPATCH_TIME_2 determines the percentage of available units at the point of dispatch of each unit. This figure is recorded with the pre-dispatch time for the given unit.

PRE_DISPATCH_TIME_3 performs the statistical analysis for construction of a frequency distribution from which GPSS functions can be developed. Appendix A displays the pre-dispatch time table. Seven columns of information are presented in the output report, in addition to the GPSS functions. This information includes the unit type to be dispatched, the percentage of units available, the elapsed time between receipt of the event by the dispatcher and dispatch of a unit, the number of cases, the percentage of each unit type/availability/pre-dispatch time class to the total, the cumulative total, and the cumulative percentage.

SECTION 5

THE COPS MODEL

5.1 ENTITY DEFINITIONS

The GPSS language employs three types of statements: control statements, block-definition statements, and entity-definition statements. Control statements perform processes common to all GPSS models, such as starting and ending a simulation run. Block-definition statements are the "verbs" of the language and cause action to take place. Units of activity are generated and terminated, system servers are seized and released, and waiting lines are queued and departed.

Entity-definition statements deserve special consideration because they correspond to the major components of the system under study. These statements are the "nouns" or subjects of the GPSS language. For example, facilities represent police officers who respond to calls-for-service (transactions). When individuals request public safety assistance, they must wait for the telephone call to be answered. Upon completing a conversation with the telecommunicator (facility), the callers must then wait for the arrival of police units. GPSS models these waiting conditions with the concept of queues.

Other entities, or modelling components, are also used. Variables, savevalues, and matrices permit data storage, calculation, and retrieval. As an example, in the model, police unit travel and service times are contained in a matrix. Ampervariables are used for input/output purposes, while storages control the number of transactions that can be processed at a given point in time.

Section 5.1 details the entities that were used in the COPS model.

5.1.1 TRANSACTION PARAMETERS

Transactions are units of activity in a simulation model. In COPS, transactions represent calls-for-service. The transactions are created when a request for police service is generated, and are terminated when the call-for-service is cleared by a police unit. In between these two points, the call is processed by telecommunicators, dispatchers, and patrol officers.

The characteristics of transactions are described by parameters. COPS employs thirty parameters for each call-for-service. An event transaction is created for the first unit which is dispatched to a call-for-service. Transaction copies are created for all assisting units. These copies are identical to the parent transaction with the exception of five parameters which hold unique values for the assisting unit.

Parameters common to each transaction are:

<u>PARAMETER</u>	<u>DESCRIPTION</u>	<u>VALID VALUES</u>
P1	Telecommunicator	81-95
P2	Call Priority	1-2
P4	Call Location	1-6
P5	Number of Cars Required For The Call	1-6
P6	Type of Call	25-28
P7	Telecommunicator Service Time	0-∞
P12	Onsite Status of Event	0-1
P13	Event Number	1-∞
P15	Event Creation Time	1-∞
P16	Service Time of First Unit	0-∞
P17	Service Time of Second Unit	0-∞
P18	Service Time of Third Unit	0-∞
P19	Service Time of Fourth Unit	0-∞
P22	Pre-Dispatch Time of First Unit	0-∞
P23	Pre-Dispatch Time of Second Unit	0-∞
P24	Pre-Dispatch Time of Third Unit	0-∞
P25	Pre-Dispatch Time of Fourth Unit	0-∞
P27	Unit Id of First Unit	0-∞
P28	Unit Id of Second Unit	0-∞
P29	Unit Id of Third Unit	0-∞
P30	Unit Id of Fourth Unit	0-∞

Unique transaction parameters are:

P3	Patrol Unit	6-17
P11	District From Which Unit Responds	1-7
P20	Order of Dispatch	1-6
P21	Service Time	0-∞
P26	Pre-Dispatch Time	0-∞

5.1.2 AMPERVARIABLES

Ampervariables are used in the model for input and output operations. An ampervariable is a type of variable preceded by an ampersand. It can be used interchangeably with savevalues, with one exception an ampervariable is not affected by CLEAR and RESET statements. Ampervariables were created when the extended IO features of GPSS/H were developed. Their principal advantages lie in readability and ease of value assignment.

The ampervariables which were employed in the model are:

1) real number arrays:

&GOAL historical percentages for comparison

2) integer arrays:

&DISTR	number of cars within each district;
&UNITDIS	district assignment of each unit;
&DP	pre-dispatch time for each unit;
&SV	service time for each unit;
&AC	action code for each unit;
&LSTCLEAR	last clear time for a unit;
&LSTSERV	last service time for a unit;

3) integers:

&MAXDIST	maximum number of districts;
&VEHICLES	total number of vehicles within zone;
&I, &J, &NUM	general purpose temporary variables;
&MAXCALLS	maximum number of calls for shift;
&TCONUM	number of telecommunicators on duty;
&HIST	creation limit for historical event data;
&PROB	creation limit for probabilistic event data;

4) character arrays:

&COMMENTS	80 characters of text;
&UNIT	3 character unit id;
&PC	3 character unit id;
&RESPONSE	3 character unit id;
&LOC	71 character street location of an event;
&LSTLOC	last event location for a unit;
&CALLTYP	actual event type;
&LSTCALL	last event type for a unit;

5) characters:

&BENCH	true or false value for benchmark run;
&ANS	general purpose temporary variable;
&TRAINING	true or false value for training module;
&ESCAPE	escape character;
&SELECT	disable or enable value for unit selection module;
&TIMES	disable or enable value for pre-dispatch, travel, and service time modules;

5.1.3 FUNCTIONS

NUMBER OF CARS

Two factors contribute to a determination of the number of cars which should be sent to an event. Since event priority is a measure of event urgency and seriousness, high-priority calls require more cars than low-priority calls. In addition, the source of a call is a factor in arriving at the number of vehicles. Officer-generated calls provide the dispatcher with more detailed information than citizen-generated calls. This level of accuracy precludes the need to send cars to

"size-up" a particular call-for-service.

Four functions are used by COPS to determine the number of cars which should be dispatched to a call-for-service. These functions are based on the priority of the call and the source of event generation, i.e. citizen or police officer. These functions are as follows:

F1 = priority 1, citizen-generated call
F2 = priority 2, citizen-generated call
F3 = priority 1, officer-generated call
F4 = priority 2, officer-generated call

Functions one through four are discrete functions with several points. The argument, random number generator 1 (RN1), is evaluated to determine the numerical result used by the model. As an example, assume the following GPSS function statement:

```
3 FUNCTION RN1,D3
.625,1/.893,2/1.000,3
```

If the random number is between 0 and .625 inclusive, the model would dispatch one unit. If the random number is greater than .625 and less than or equal to .893, two vehicles would be dispatched. If the random number is greater than .893, three units would be required.

These functions derive their distribution from the data gathered by the data collection program UNITS PER EVENT.

PRE-DISPATCH TIME

The pre-dispatch time associated with a unit is the delay between receipt of a call and dispatch of a unit. This time may occur because the dispatcher is involved in other activities or because of a lack of vehicles. In the first instance, a dispatcher may be performing a vehicle registration inquiry, dispatching a vehicle to another event, or contacting a tow truck company. In the second instance, an absence of patrol units in the area of the call may contribute to a delay in dispatch.

Eight discrete functions define the pre-dispatch time for events, based on the percent of vehicles available for dispatch and the type of unit required, i.e. primary or assisting. A shorter pre-dispatch time would be expected for primary units since the dispatcher's first goal is to initiate a response. Similarly, lower pre-dispatch times should be observed if all units are available for dispatch, as opposed to only 50%.

These functions are as follows:

F11 = 100%	unit availability; primary unit is required;
F12 = 80-99%	unit availability; primary unit is required;
F13 = 60-79%	unit availability; primary unit is required;
F14 = 0-59%	unit availability; primary unit is required;
F15 = 100%	unit availability; assisting unit is required;
F16 = 80-99%	unit availability; assisting unit is required;
F17 = 60-79%	unit availability; assisting unit is required;
F18 = 0-59%	unit availability; assisting unit is required;

These functions derive their distribution from the data gathered by the data collection program PRE-DISPATCH TIME.

TELECOMMUNICATOR SERVICE TIME

Telecommunicator service time functions represent the time in seconds that telecommunicators spend processing calls-for-service. This time begins when a call is answered by a telecommunicator, and ends when the event is transferred to the dispatcher by the computer-aided dispatch system. The types of calls handled by telecommunicators can be classified in a variety of ways. For the purpose of the COPS model, the calls are categorized by the nature of the interview which needs to be performed.

In the Monroe County 911 Center, police, fire, and emergency medical service (EMS) calls are processed by a common group of telecommunicators. Fire calls demand the quickest interview, because the caller needs to exit the location where the fire is burning. EMS calls require a more detailed interview in order to determine if basic life support or advanced life support assistance is required. Police calls typically consume the longest amount of time because of the need for detail. Suspect descriptions, direction of travel, and type of crime are only three areas where a discussion between caller and telecommunicator can occur.

Four discrete functions have been developed to determine the length of a telecommunicator interview, based on the type of call, i.e. police, fire, or emergency medical service. In addition, police calls have been further divided into central-dispatch and agency-transfer types of calls. Central-dispatch police calls require a full interview. Agency-transfer police calls necessitate an abbreviated interview because the local police agency will conduct a more detailed interview.

The four functions are as follows:

- F25 = central-dispatch police call;
- F26 = agency-transfer police call;
- F27 = fire call;
- F28 = emergency medical services call;

These functions derive their distribution from the data gathered by the data collection program TELECOMMUNICATOR SERVICE TIME.

EXPON

EXPON is a continuous, twenty-four point function which is used to generate interarrival times between calls-for-service. It has one argument, random number generator 1 (RN1). The exponential function is used because of its relationship to the Poisson distribution.

The Poisson distribution describes random phenomena which occur over a fixed period of time. In order for a process, such as the arrival of police calls-for-service, to be described by the Poisson probability function, four postulates must hold true:⁶

Postulate 1. The process is *independent*, i.e., the numbers of occurrences in non-overlapping time intervals are statistically independent.

Postulate 2. The process is *stationary*, i.e., the number of occurrences in a time interval has the same probability distribution for all time intervals.

Postulate 3. The probability of one occurrence in any time interval . . . is approximately proportional to the size of the interval . . .

Postulate 4. The probability of two or more occurrences in any time interval . . . is negligibly small, relative to the probability of one occurrence in the interval.

If these four postulates hold, the number of occurrences in a unit time interval follows a Poisson probability distribution with parameter $[\lambda]$.

The Poisson and exponential probability distributions are used in conjunction with each other. Statistical theory notes that:⁷

If the occurrences are generated by a Poisson process . . ., the lengths of time between successive occurrences are statistically independent random variables from an exponential distribution.

DIST

DIST is a seven-point discrete function which uses the district from which a patrol unit responds (PARAMETER 11) as its argument. This function is used as an offset into MATRIX TRAVEL which determines travel time.

ARVORD

ARVORD is a six-point discrete function which uses the order of dispatch (PARAMETER 20) as its argument. The function is used as an offset into MATRIX SERVICE which determines service time.

PRI

PRI is a two-point discrete function which uses the priority of the call (PARAMETER 2) as its argument. The function is used as an offset into MATRIX TRAVEL and MATRIX SERVICE.

5.1.4 VARIABLES

INTRAT is the intra-district travel time variable. It represents the time which a patrol unit incurs when responding to calls-for-service which occur within its home district.

INTERT is the inter-district travel time variable. It represents the response time which a patrol unit incurs when the unit travels to events outside of its home district.

INTRAS, like INTRAT, calculates intra-district time. However, INTRAS records the amount of time that a unit spends servicing calls which occur in its home district.

INTERS is the inter-district service time variable which represents the time that units spend servicing calls which occur outside of the unit's home district.

VARIABLES 1-7 contain the number of cars assigned to a specific district. The values which are placed in variables 1-7 are entered by the analyst at the beginning of the simulation run. They are assigned from ampervariable array DISTR.

VARIABLES 10-17 contain the first unit of the district. For example,

11 VARIABLE 6

12 VARIABLE $V_{11} + V_1$

VARIABLE 12 equals the facility number of the first unit in district 1, i.e. 6, plus the number of cars assigned to district 1.

Taken together, VARIABLES 1-7 and 10-17 permit the model to identify the facility numbers of the patrol units in each district.

VARIABLES 30 - 53 are used in the probabilistic event generation mode to represent the interarrival time of calls-for-service. The variables are of the form $B_n P_n [C \text{ or } O]$.

Each variable represents the three primary characteristics of a call type, i.e. the district in which the call is located, the priority of the call, and the way in which the call was reported to the communications center. "B" is the zone of call origination and "n" is the district number; " P_n " is the priority of the call-for-service; and "C" or "O" is the source of the call, i.e. citizen or officer-generated.

The following example illustrates this syntax:

B1P1C - District B1, Priority 1, Citizen Generated

VARIABLES 66-77 and **81-95** evaluate the idle time of each patrol unit and telecommunicator facility, respectively.⁸ For example,

66 VARIABLE $(1-F_6) * (1000-FR_6)$

$(1-F_6)$ evaluates to "0" if FACILITY 6 is in use, and to "1" if FACILITY 6 is idle. Thus, the variable assumes a positive value only if the facility is available. This value is $(1000-FR_6)$, where FR is facility utilization in parts per thousand. $(1000-FR_6)$ is, therefore, the amount of idle time for FACILITY 6.

These variables are used in a SELECT MAX statement to identify the variable with the largest idle time, and consequently, the smallest facility utilization.

5.1.5 STORAGES

Storages are entities that hold a user-defined number of transactions, thereby limiting the number of "events" which can be processed at any given time. In the COPS model, the total number of calls that can be simultaneously handled by telecommunicators is defined by storage TCOS. If more than TCOS number of calls demands service at the communications center at the same time, the excess calls wait in a queue until the storage can accommodate new transactions.

5.1.6 SAVEVALUES

MATRIX TRAVEL is a table of district travel times. There are six rows and fourteen columns in TRAVEL. Each row number corresponds to a district where a call-for-service could occur. Each column number is calculated by referencing **FUNCTIONS DIST** and **PRI**. The **TRAVEL TIME MODULE** discusses the use of this matrix in detail.

MATRIX SERVICE is a table of district service times. Like the preceding matrix, there are six rows which correspond to the districts where a call-for-service could occur. Each of the twelve column numbers is calculated by referencing **FUNCTIONS ARVORD** and **PRI**. The **SERVICE TIME MODULE** discusses the use of this matrix in more detail.

MATRIX PLAN contains an ordered list of patrol districts which should be searched for patrol units. **PLAN** contains six rows which correspond to the six districts where events may occur. There are also seven columns in **PLAN**. The columns represent the primary, secondary, tertiary, etc. order of districts from which units should be chosen. For example, if a call-for-service occurs in district three, **MATRIX PLAN** would advise the model to begin looking for available units in district three, followed by a list of nearby districts.

Several non-matrix savevalues are used to store values. The **DISPATCH PLAN AND UNIT SELECTION MODULE** uses four of these savevalues. **FIRST** and **LAST** represent the first and last units within a given district, respectively. **LEVEL** records the stage of the dispatch plan which is being searched, e.g. 1 = primary district, 2 = secondary district, etc. **DISTNUM** is the district within a given **LEVEL** which is being searched for available units.

Eighty savevalues, numbered 20 through 99, are used to record values which represent inter and intra-district travel and service times. **SAVEVALUES 20-39** and **60-79** represent intra-district response times and service times, respectively. **SAVEVALUES 40-59** and **80-99** represent inter-district response times and service times, respectively. Because **SAVEVALUES 20-99** contain the result of a division process, they have been defined as floating point, or long, savevalues.

The **TRAINING MODULE** uses **SAVEVALUE TEMPL**, **HR**, **HRL**, and **MINL** to record time information. This module also updates the total number of dispatches in **SAVEVALUE TOTAL** and the correct selections chosen by the analyst in **SAVEVALUE RIGHT**.

Several savevalues are used to temporarily hold values. To increase the readability of the code, separate savevalues were used instead of a common "temporary". **SAVEVALUES PATROL**, **MAXCAR**, and **AVAIL** are defined in the model.

5.1.7 FACILITIES

TELECOMMUNICATORS and PATROL UNITS

Facilities are the "servers" in GPSS. They operate on transactions by holding the transaction for a specified period of time. The COPS model includes fifteen telecommunicator facilities, and twelve patrol unit facilities.

5.1.8 QUEUES

All transactions which flow through the telecommunications process enter **QUEUE TELCO**. The queue records statistics which provide information on the amount of time callers wait for a telephone call to be answered. This queue is departed after initiation of service by a telecommunicator.

ZONEQ and QUEUES 1 - 6 accept transactions in the **NUMBER OF CARS MODULE**. These queues capture waiting line statistics from the moment the call is received by a dispatcher until the moment the patrol unit is dispatched in the **DISPATCH MODULE**. **ZONEQ** represents the queue for the entire police jurisdiction under study, while **QUEUES 1-6** represent district queues.

5.1.9 TABLES

TABLE PREVPAT captures data related to the number of cars patrolling the zone. Every minute of simulated time, the model scans the status of patrol units and enters the number of idle cars into the table.

TABLES 1 - 8 record primary unit travel times in each of the districts. The tables therefore represent the response time for the first unit to an event, as opposed to the response time for all units.

TABLES 11 - 18 record primary unit service times in each of the districts.

5.1.10 FILES

In order to achieve maximum program flexibility, input data is rarely coded in the model. Instead, data is read from several files upon initiation of the COPS model. The **RESOURCE ASSIGNMENT MODULE** describes many files, including **UNITF**, **DPLANF**, **TRAVELF**, **SERVICEF**, **ADDRESSF**, **CALLSF**, and **ESCAPEF**. The **HISTORICAL EVENT GENERATION MODULE** discusses the use of the **EVENTSF** file. The **EVENT LOG MODULE** prints event activity to file **LOGF**. Section 6 of the thesis describes the output tables which are written to file **RESULTSF**.

5.2 MODULE DESCRIPTIONS

Section 5.2 explains the logic of each module used in the COPS system. Appendix D includes a block diagram showing the relationship of the modules.

5.2.1 RESOURCE ASSIGNMENT MODULE

COPS **initializes district resources** by assigning values to system ampervariables and savevalue matrices. The maximum number of districts is established in &MAXDIST, the number of units per district is assigned to array &DISTR, and the total number of vehicles is placed in &VEHICLES. The name of each police unit and its district assignment are then read from FILE UNITF into array &UNIT and array &UNITDIS, respectively. The dispatch plan for the police jurisdiction is read from FILE DPLANF and placed into savevalue matrix MX\$PLAN. Police travel times, i.e. the times between dispatch and arrival at the scene, are assigned from FILE TRAVELF to savevalue matrix MX\$TRAVEL. Service times, i.e. the times from arrival of units at the scene to clearance from the event, are read from FILE SERVICEF and placed into savevalue matrix MX\$SERVICE.

The "escape" character is read into the model from FILE ESCAPEF in order to take advantage of the escape sequences associated with VT100 screen attributes, scrolling regions, and cursor movement commands. (The VT100 terminal characteristics were used because of the availability of this type of terminal to the author of this thesis. The COPS model should be modified to prompt the analyst for the type of terminal. If it is not a VT100, the terminal characteristics should be disabled.) The screen is then cleared and set to reverse-video, and a welcome message displayed for the analyst.

The interactive **resource assignment process** now commences. COPS begins this interactive session by displaying the police unit assignments for each district in the police jurisdiction. The analyst is then prompted to accept the default district assignments or enter new values. If the analyst desires to update the default listing, the model allows the re-definition of all district parameters, i.e. the number of districts, the number of units per district, and the actual vehicles assigned to each district.

The dispatch plan is then displayed for the analyst. The dispatch plan presents the order in which districts are scanned for available police units. The analyst may accept the default dispatch plan, or enter new values.

Finally, the analyst must determine the number of telecommunicators which are assigned to answer calls and perform interviews. Storage TCOS is updated with the value that the user enters.

The system then requests the **type of event generation**. The analyst is provided the choice of selecting historical data or allowing the model to operate in a probabilistic mode. This latter selection requires the model to generate events according to the interarrival times that have

been defined in the model, and to enable all modules within the model.

If the analyst selects the historical option, the system reads the addresses of each event from FILE ADDRESSF and places this data into array &LOC. Event types are then read from FILE CALLSF and placed in array &CALLTYP.

The COPS model therefore contains the ability to generate transactions by two means. In order to select one method over the other, the creation limit feature of the GENERATE statement is used. For example, when the analyst chooses historical event generation, &HIST is set to 1 and &PROB is set to 0. The HISTORICAL EVENT GENERATION MODULE produces one driving transaction, while the PROBABILISTIC EVENT GENERATION MODULE generates no events. These modules are described in detail below.

Establishing the **degree of modelling** is the next phase of the pre-simulation process. "Degree of modelling" refers to the extent to which all of the COPS modules are used in calculating results. When the historical option is chosen, calls-for-service are generated according to actual experience. Historical event generation does not, however, mandate that historical unit information must be used. The analyst may choose to have patrol units selected by the model or from historical data. Likewise, times associated with the units may be derived from COPS modules or from actual data.

If the analyst chooses to disable certain modules in the model because the data will be supplied from historical experience, COPS is not utilizing the full power of the model to perform the simulation of police activity; hence, a lesser degree of modelling. The analyst may decide to have units recommended by model logic, but use actual unit times associated with a specific call-for-service. Or, the analyst may require the model to determine the selection of units and pre-dispatch, travel, and service times.

This set of choices is used to define a benchmark version of the simulation model. The purpose of a benchmark is to use historical event and unit characteristics in order to compare simulation results with actual experience. The benchmark is actually a development and validation aid which serves as a reference point for other simulation runs.

If the benchmark alternative is selected, COPS disables the DISPATCH PLAN AND UNIT SELECTION MODULE, as well as the PRE-DISPATCH TIME, TRAVEL TIME AND SERVICE TIME modules. Actual data, i.e. unit and event characteristics obtained by the HISTORICAL EVENT GENERATION MODULE, are used by COPS. Because the unit selection and time-related modules are disabled, the benchmark is a test of event-flow logic through the model and the subsequent recording of statistics associated with the run.

The model then asks the analyst to enter target utilization goals for each unit. These goals are used to verify that the model replicates reality when used with historical data in a benchmark environment. These figures must be gathered from the CAD patrol-unit-activity evaluation

program.

The analyst may then decide if he/she wishes to invoke the **interactive training component** of the model. This feature allows the analyst to compare his/her choices of unit selection with actual dispatches (for the historical mode) or with the computer's decisions (for the probabilistic/full modelling mode).

5.2.2 PROBABILISTIC EVENT GENERATION MODULE

Twenty-eight event generation routines comprise the **PROBABILISTIC EVENT GENERATION MODULE**. The first four routines generate calls for agencies other than the Monroe County Sheriff's Department. These routines involve three statements. The first line of code generates calls at an interarrival mean which has been established by the **PROBABILISTIC EVENT GENERATION** data collection program. The second statement classifies the call as police central-dispatch, police agency-transfer, fire, or emergency medical services. The third statement transfers control to the **TELECOMMUNICATOR MODULE**.

Twenty-four event generation routines are provided for calls to the Monroe County Sheriff's Department, based on district of call origination, call priority, and source of call, i.e. officer-generated or citizen-generated. This information has been established by the **SHERIFF'S EVENT GENERATION** data collection program. Each of the six Sheriff's Zone B districts has four event generation routines, as determined by the combination of district, priority, and call-source values.

For example:

District 1 - Priority 1 - Citizen Generated
District 1 Priority 2 - Citizen Generated
District 1 Priority 1 - Officer Generated
District 1 - Priority 2 - Officer Generated

Each of the event generation routines for citizen calls has five statements, while onsite event generation includes an additional statement. The first statement of each routine determines the rate at which events are generated.

It is of the form:

GENERATE $B_x P_y C/O$, FN\$EXPON,,&PROB,,30

The variable $B_x P_y C/O$ represents one of the four combinations outlined above. B_x is the district in Zone B; P_y is the priority of the call; and C/O is either citizen or officer event-generation. These variables are initialized prior to the beginning of simulation.

The function FN\$EXPON has been described in detail in Section 4. The interarrival mean $B_x P_y C/O$ is modified by the exponential function to determine the time of the next event.

The ampervariable &PROB represents the creation limit of the GENERATE statement and holds a value of 0 or 99. If the historical mode has been selected, &PROB creates no transactions; otherwise, it creates a maximum of ninety-nine transactions.

The value thirty at the end of the GENERATE statement permits a maximum of thirty parameters to be assigned to each transaction.

The second statement in each event generation routine assigns the priority of the call to PARAMETER 2. The third statement assigns the district of call origination to PARAMETER 4. It is one through six for Sheriff's events, and zero for all other agencies. The fourth statement assigns the time of event creation to PARAMETER 15. The next statement applies only to onsite event generation. It assigns a one to PARAMETER 12 to identify these transactions as originating with a police officer. The last statement of each event generation routine transfers control to one of two locations in the model. For citizen-generated calls, transactions are forwarded to the TELECOMMUNICATOR MODULE. Onsite events bypass the telecommunicator phase and pass directly to the NUMBER OF CARS MODULE.

5.2.3 HISTORICAL EVENT GENERATION MODULE

COPS accesses event and unit attributes from file EVENTSF for each call-for-service that occurs within a given shift. The data in EVENTSF was collected by the HISTORICAL EVENT GENERATION data collection program.

The model reads an "event" from FILE EVENTSF and assigns the call-for-service characteristics to the parameters of a "driving" transaction.⁹ The term "driving" refers to the fact that the transaction is used to record the characteristics of the call, copy these characteristics (parameter values) to another transaction, and loop to the beginning of the module to accept the characteristics of the next call-for-service. This repetitive read-and-copy routine drives the historical event generation module. Hence the term "driving" transaction.

Four event characteristics are assigned directly to transaction parameters. PARAMETER 15 receives the relative time of event creation; PARAMETER 4 is assigned the district of call origination; PARAMETER 2 holds the priority of the event; and PARAMETER 5 maintains the number of cars which are to be dispatched to this event.

Unit characteristics are then assigned to four arrays. &PC(x) is the three character unit name. &DP(x) is the pre-dispatch time for the vehicle. &SV(x) is the combination of travel time and service time for the patrol unit. &AC(x) is the code for the type of service that the unit provided at the scene of the call-for-service, e.g. prepared a report, made an arrest, issued a ticket.

Prior to reading the next event, the three-character unit id contained in the array &PC is converted to a numerical patrol facility by comparing the unit name to each element of the array &UNIT. This value is assigned to PARAMETER[26 plus offset], while the pre-dispatch and

service times are assigned to `PARAMETER[21 plus offset]` and `PARAMETER[15 plus offset]`, respectively. The offset represents the ordinal value of the unit that has been dispatched, i.e. first, second, etc. As an example, `PARAMETER 16` would hold the service time of the first unit, while `PARAMETER 17` would contain the service time of the second unit. The assignment of unit characteristics to transaction parameters continues for each car that is dispatched to the event.

The "driving" transaction then waits until the time of call creation (`P15 - C1`). At that point, the "driving" transaction creates a clone using the `SPLIT` operator, and transfers the cloned "event" transaction to the `NUMBER OF CARS MODULE`. The "driving" transaction loops to the beginning of the `HISTORICAL EVENT GENERATION MODULE` where the process is repeated until such time that `FILE EVENTSF` becomes empty. At this point, control passes to `BLOCK EXIT` in `SYSTEM CLOCK MODULE`.

Appendix D includes a block diagram of the `HISTORICAL EVENT GENERATION MODULE`.

5.2.4 TELECOMMUNICATOR MODULE

At the 911 Communications Center, telecommunicators are assigned incoming calls. The automatic call distribution (ACD) system assigns each call to the telecommunicator with the longest idle time. Upon receiving a call, the telecommunicator is excluded from receiving any other calls until the current one is completed. After the telecommunicator terminates the interview of the calling party, final event data is entered into the CAD system. When the event is transferred to a dispatcher, the telecommunicator signals the ACD that he/she should be considered for another call.

To reflect this activity, the `TELECOMMUNICATOR MODULE` accepts a call into `QUEUE TELCO` which is analogous to the automatic call distribution system. `STORAGE TCOS` is then checked to find if the maximum number of calls is being serviced. If so, the call waits at this point in the module. Since telecommunicators can only handle one call at a time, `TCOS` also reflects the number of available telecommunicators.

If telecommunicators are available, the one with the longest idle time is selected. This is accomplished in `COPS` by use of a `SELECT MAX` statement. The telecommunicator with the lowest utilization is obtained from the evaluation of a telecommunicator variable in the form $(1-F_x) \cdot (1000-FR_x)$.¹⁰ $(1-F_x)$ is 1 for idle telecommunicators and 0 for busy telecommunicators. FR_x is the facility utilization, in parts per thousand, for telecommunicator x . $(1000-FR_x)$ is, therefore, the amount of idle time.

`STORAGE TCOS` is decremented by one to indicate the change in status of a telecommunicator. A telecommunicator facility is then seized and `QUEUE TELCO` is departed, corresponding to the delivery of the call.

The service time for the call is then calculated, based on the type of call. Four categories are possible: central dispatch of police calls, agency transfer of police calls, fire calls, and emergency medical service calls. Data is gathered for these call classes in the TELECOMMUNICATOR SERVICE TIME data collection program. Each of the classes is represented in the model by a probability function. At event generation time, the type of call is stored in PARAMETER 6. Therefore, at this point in the process, the function representing the particular class is evaluated, (FN*P6), and the result placed in PARAMETER 7. An ADVANCE BLOCK waits the time specified in PARAMETER 7 to reflect the interview of the calling party and the subsequent entry of data into the CAD system.

At the conclusion of the time period, the telecommunicator facility is released and STORAGE TCOS is incremented to show the availability of another telecommunicator. PARAMETER 4 of the transaction is then evaluated to determine the district of call origination. If the value is in the range of 1 through 6, the call is a Sheriff's event. If the value is 0, the call should be handled by another agency. Sheriff's calls are transferred to BLOCK DISP of the NUMBER OF CARS MODULE, while all remaining calls are terminated in the model.

Two additional GPSS statements must be explained. Prior to entering QUEUE TELCO at the beginning of the module, each call is tested to determine if it is a Sheriff's call. If so, PARAMETER 6 of the transaction is updated to show that it is a central-dispatch type of call. The second statement of interest is a test for historical data generation. If events have been read from file EVENTSF, the telecommunicator process is skipped.

5.2.5 THE DISPATCH PROCESS

When the Sheriff's dispatcher receives a new event, a one line summary of the call appears on the dispatcher's screen. After completing his/her current activity (dispatching a car; making a notify; obtaining license information), the dispatcher views the entire call which the telecommunicator has prepared. Prior to displaying this event for the dispatcher, the CAD system searches a dispatch plan file. This file contains the district assignments for the location where service is required. CAD scans each district until available units are found. Up to six car ids are then presented for the dispatcher. In addition, the CAD system searches a response file to find the dispatch instructions for the particular call-for-service. The dispatch information essentially states the number of vehicles that should respond to the call. The dispatcher views the preceding data, as well as the remarks which have been appended to the event form by the telecommunicator. Dispatch of the appropriate units then occurs.

The COPS model follows this scenario very closely. The following modules determine the appropriate patrol unit(s) to dispatch to an event.

5.2.6 NUMBER OF CARS MODULE

Upon encountering this module, the transaction enters a district queue (QUEUE P4) and a general zone queue (ZONEQ). These queues are used to record waiting statistics for each district, as well as the entire zone. The sequential event number for the shift is assigned to PARAMETER 13 by counting the number of events that have passed through BLOCK DISP. Furthermore, the transaction is identified as the primary car transaction for this event (as opposed to an assisting unit) by assigning the value of one to PARAMETER 20.

One of four functions determines the number of cars which should respond. The functions are based on call priority and the source of call generation, i.e. citizen or officer. Each function uses a random number generator and a probability distribution to calculate the actual number of cars that the dispatcher needs to dispatch. This number is placed in PARAMETER 5.

If two or more units are required, COPS creates additional transactions. The number of assisting units translates into additional transactions. The SPLIT operator creates the appropriate number of "assisting" transactions (PARAMETER 5 - 1). The number of each assisting transaction, i.e. 2, 3, etc., is placed in PARAMETER 20. Therefore, PARAMETER 20 reflects the order of dispatch for the unit. Primary and assisting transactions pass on to the DISPATCH MODULE.

5.2.7 DISPATCH PLAN AND UNIT SELECTION MODULE

The computer-aided dispatch system verifies a location by finding it in the *street file*, and assigning a unique police area number. CAD then searches the *dispatch plan file* for the particular police area. Once found, the dispatch plan record provides the primary car territory and supplementary car territories for the location of interest. Using these territories in the order given by the dispatch plan file, CAD enters the *police unit file* and locates the first six available units. Idle units assigned to the primary car territory are selected first, followed by units which are assigned to the supplementary districts.

The COPS model follows the logic of this search routine. The dispatch plan is contained in MATRIX PLAN. The DISPATCH PLAN AND UNIT SELECTION MODULE uses two pointers, LEVEL and DISTNUM, to search the plan until a district with at least one available unit is found. SAVEVALUE LEVEL equates to the order of the district, i.e. 1=primary, 2=secondary, 3=tertiary, etc., while DISTNUM is the district number. Initially, SAVEVALUE LEVEL is set to 1. A district is then selected from MATRIX PLAN by searching for the row and column identified by PARAMETER 4 and SAVEVALUE LEVEL, respectively. Each row contains the dispatch plan for a given district. The columns represent the primary, secondary, tertiary, etc. districts for unit selection.

The value of DISTNUM is increased by 10 to correspond to the variable which contains the facility number of the first car in the district. This value is assigned, appropriately, to SAVEVALUE FIRST. As an example, let DISTNUM equal 1 for district 1. After completion of the assignment, SAVEVALUE FIRST contains the value of VARIABLE 11, i.e. the value 6. The value LAST is then calculated. SAVEVALUE LAST represents the last car in the given district, and is determined by adding the total number of vehicles in the target district to the facility number of the first vehicle in the district.

The GPSS operator SELECT finds the first patrol facility which is not used (NU). Patrol facilities are scanned from the FIRST unit to the LAST unit of the district. If found, the facility number is assigned to PARAMETER 3. If no units are available, control passes to BLOCK DISPLAN where the next supplementary district (secondary, tertiary, etc.) is assigned to SAVEVALUE LEVEL, thereby causing the corresponding district number to be assigned to SAVEVALUE DISTNUM. If all units in all districts are already dispatched, the model waits one second and begins the scan of the dispatch plan from the beginning.

The model employs an option in the DISPATCH PLAN AND UNIT SELECTION MODULE. In addition to being able to assign the first available unit to a call-for-service, the model allows the user to assign the unit with the lowest utilization factor. Given a district with more than one unit, the "first-available-unit-selection" method may inappropriately assign the majority of events to the first unit. Even though the computer-aided dispatch system displays the units in sequential order, the dispatcher does distribute the workload among several units assigned to a single district.

In like fashion, the COPS model can determine the unit that has been available the longest amount of time in a given district, and assign the job accordingly. The algorithm outlined above holds true. However, after the model determines that there is at least one available unit in a given district (via the SELECT statement), the model uses another SELECT statement to determine the unit with the maximum idle time.

It should be noted that this SELECT statement actually identifies the VARIABLE, in the range from FIRST to LAST, with the maximum idle time. How does this equate to a patrol facility, and why are the patrol facilities not selected directly?

The answer to the latter question is found in the structure of the SELECT statement.¹¹ Only one condition, e.g. "nu", "max", "min", can be selected. To find the patrol facility that does, in fact, meet these two conditions ("maximum idle time" and "not used"), variables are created in equal number to the patrol facilities.

The VARIABLE declarations are in the following form:

VARIABLE $(1-F_x)*(1000-FR_x)$

If FACILITY x is idle, then $(1-F_x)$ equals 1.

If FACILITY x is in use, then $(1-F_x)$ equals 0.

$(1000-FR_x)$ is the proportion of idle time.

FR is facility utilization in parts per thousand.

Upon encountering the SELECT MAX statement, the model evaluates each "facility" variable. The facility utilization figures of the idle variables are compared in the range of FIRST to LAST. The VARIABLE with the maximum idle time corresponds to the facility with the minimum utilization time. This number is assigned to PARAMETER 3. Control then passes to BLOCK DISP3 in the DISPATCH MODULE.

5.2.8 HISTORICAL TIMES MODULE

Pre-dispatch times and service times may be obtained from historical data. A transaction may hold several pre-dispatch times and several service times, depending on the number of units which are dispatched to an event. Pre-dispatch times are reserved in PARAMETERS 22-25, while service times are reserved in PARAMETERS 16-19. Thus, every transaction for an event contains the times of all units (up to a maximum of four units) which have been dispatched to the event.

It is the responsibility of the HISTORICAL TIMES MODULE to determine which of the parameters holding the reserved times need to have their values assigned to PARAMETERS 21 and 26, i.e. the service time and pre-dispatch time of the current unit. In order to accomplish this task, the module adds the dispatch order of the vehicle, i.e. first, second, third, to a fixed starting point and arrives at the appropriate unit parameter containing the reserved value. The assignments are made to PARAMETERS 26 and 21, for pre-dispatch and service times, respectively. Control then passes to the DISPATCH MODULE.

5.2.9 PRE-DISPATCH TIME MODULE

After an event is entered into the computer by the telecommunicator, the event is routed to the dispatcher having control for the location in which the call-for-service originated. An event will typically wait a period of time before the dispatcher selects a unit for assignment to the event. This delay may occur because of other activities which the dispatcher is performing, or because of a shortage of cars in the area of the call.

Eight functions have been derived to determine the amount of time that the event waits at the dispatcher's workstation prior to dispatch. This pre-dispatch time is dependent on two factors: (1) the type of vehicle to be dispatched, i.e. primary or assisting, and (2) the availability of units for dispatch. Four availability categories have been identified: 100% , 80-99%, 60-79%, and 0-59%.

Data for these categories has been collected for primary units and assisting units, thereby yielding eight functions.

The module begins by counting the unused patrol facilities. If a call requires more than one unit, the total number of available units must be decreased by the preceding units for this call, since these units were shown as available when the count of unused facilities was conducted. (Pre-dispatch times are calculated for all units assigned to an event before the dispatch of any individual unit.) This number is divided by the total number of district cars to produce an availability percentage. After finding the category in which the availability percentage lies, the type of unit is determined by looking at PARAMETER 20 (the order of dispatch). If PARAMETER 20 equals one, the unit is primary and the function lies between F11 and F14, otherwise the function is in the range of F15 through F18.

Each function employs a random number generator and a probability distribution to calculate the pre-dispatch time. The derived value is assigned to PARAMETER 26, whereupon control transfers to the DISPATCH MODULE.

5.2.10 DISPATCH MODULE

The DISPATCH MODULE acts as a key interface to several other modules. Upon entering this module from the NUMBER OF CARS MODULE, the ampervariable &TIMES is evaluated to determine if the COPS model is to calculate the pre-dispatch time for the event. The onsite status of the unit transaction is also checked. Since onsite events are created by units, there is no pre-dispatch time associated with the primary unit on such an event. If &TIMES is enabled, and if the unit is not an "onsite" unit, control passes on to the PRE-DISPATCH TIME MODULE. If historical-time data is to be used, however, control passes on to the HISTORICAL TIMES MODULE. Control returns to BLOCK DISP2.

At BLOCK DISP2, the transaction waits until the unit is to be dispatched. This time equates to the time of call receipt plus telecommunicator service time plus pre-dispatch time less current clock time ($P15+P7+P26-C1$).

The ampervariable &SELECT is then checked to determine if units are to be chosen from historical data or by the model. If historical data is to be used, the appropriate patrol facility number is assigned to PARAMETER 3. Otherwise, control passes to the DISPATCH PLAN AND UNIT SELECTION MODULE. After assignment of the patrol unit to PARAMETER 3, BLOCK DISP3 is reached.

BLOCK DISP3 calls the TRAINING MODULE in order to allow the analyst to interact with the simulation model. Upon return from this module, the patrol unit which has been selected for dispatch is seized, and its district is recorded in PARAMETER 11. The transaction is tested to determine if it contains the primary unit for the event. If so, QUEUE ZONEQ and QUEUE P4 are

departed. (The primary unit transaction had entered these queues in the NUMBER OF CARS MODULE.)

All unit transactions then pass on to the TRAVEL TIME MODULE, which in turn calls the SERVICE TIME MODULE. At the completion of the call servicing time, control returns to BLOCK FINISH where the patrol unit is released. The transaction then passes on to the EVENT LOG MODULE.

Appendix D includes a block diagram of the DISPATCH MODULE.

5.2.11 TRAVEL TIME MODULE

Upon dispatch by the Sheriff's dispatcher, the patrol unit travels to the location of the call-for-service. The total length of time between dispatch of the event and arrival of the unit at the scene is known as travel time. In reality, the deputy may not initiate an immediate and direct response to the event. He/she may complete the activity that is currently in progress, may be preempted by another call-for-service which is of higher priority or closer to his/her location, or may travel a circuitous route to the final destination.

For non-benchmark runs, COPS models the amount of time between dispatch and arrival by selecting the appropriate value in MATRIX TRAVEL, using the home district of the patrol unit and the priority of the event as offsets into the table. Thus, each of the patrol districts maintains a unique set of values for each unit district/call priority combination. For benchmark runs, control is passed directly to the SERVICE TIME MODULE.

PARAMETER 4 identifies the district where the call occurred, while functions DIST and PRI contain the offsets for unit location and call priority, respectively. These functions determine the column in the table which contains the actual travel time. Therefore, the unit travels from district PARAMETER 11 to district PARAMETER 4 at a speed that considers the urgency (PARAMETER 2) of the call. For example, if a priority-two call occurs in district three, and a unit from district four has been selected for dispatch, column eight of row three contains the travel time (row = call location = parameter 4 = row 3; column = function DIST + function PRI = 7 + 1 = column 8). The travel time is assigned to PARAMETER 10.

If the total travel time would exceed the end of the shift, travel time is modified to reflect the difference between the current time and the end of the shift. In fact, this logic is implicitly employed by the GPSS language in calculating facility statistics. Time is recorded up to the end of the simulation run, i.e. the conclusion of the shift. Results must be reviewed with the understanding that units continue to travel to calls and provide service across shift boundaries. For statistical purposes, however, results are provided only for the duration of the given shift. This logic could be modified to terminate the simulation run after all cars cleared from events which originated during the shift. In that case, statistics would reflect total travel and service times.

The TRAVEL TIME MODULE calculates the intra-district and inter-district travel times for the specific patrol facility which is travelling to the scene. If the incident district is equal to the unit's district, the savevalue location determined by the variable INTRAT is increased by the response time; otherwise, the savevalue location represented by the variable INTERT is increased to update the inter-district travel time cumulative total for the patrol unit.

The unit transaction now waits the length of time contained in PARAMETER 10. After the response time for the current call elapses, PARAMETER 10 is divided by 60 to convert the time into minutes. If the unit was primary on the call, TABULATE statements update the district and zone response time tables. The model then calls SERVICE MODULE, which calculates the amount of time that the unit spends at the scene.

5.2.12 SERVICE TIME MODULE

After arriving at the scene where police assistance has been requested, service is rendered by the patrol unit. In fact, a call may require more than one officer. In such a case, the first unit on the scene becomes the primary unit, while all others are known as backup or assisting units. The service times are different for the units in most cases.

The COPS model must therefore determine service time for each officer who travels to a call-for-service. For benchmark runs, the actual total of travel and service time is used. For non-benchmark runs of the model, a matrix of times is maintained for each of the districts in Zone B. Unlike the travel time module, however, the district of the responding unit does not play a role in calculating service time. It is the dispatch order of the units and the priority of the event which determine the specific table value. Functions ARVORD and PRI provide offsets into MATRIX SERVICE. (Please refer to the example in the TRAVEL TIME MODULE for an illustration of the use of offsets.)

The rationale for this logic is straightforward. The first car dispatched is designated the primary unit for the event. As such, the officer is responsible for providing service and completing a written report of the event. Assisting units do not have this reporting requirement. Furthermore, backup units are typically dispatched at some point after the primary unit. Therefore, the service time is shorter, even if the assisting units stay as long as the primary unit. Lastly, assisting units often travel to an event, only to find the situation under control. After a cursory check, they return to patrol duty. For these reasons, the dispatch order of units is considered an important factor in determining service time.

In either case, if the total service time would exceed the end of the shift, service time is modified to reflect the balance of time between the current time and the end of the shift. This is done because all statistics are gathered only for the duration of the shift.

The location of the call (PARAMETER 4) is then compared with the home district of the responding unit (PARAMETER 11). If the two parameter values are equal, the savevalue location determined by variable INTRAS is incremented by the unit's service time. If the unit has provided service outside of his/her home district, the savevalue location represented by variable INTERS is updated.

The required amount of service time elapses. Two array elements are updated. &LSTSERV records the service time for the patrol facility listed in transaction PARAMETER 3. &LSTCLEAR is assigned the current clock time (C1) for the same patrol unit. These times are used in the TRAINING MODULE to show the most recent service and clearance times for each unit.

Service time is then converted to minutes. TABULATE statements are employed to record the service time of the primary unit in the district and zone service time tables. Control of the transaction returns to the DISPATCH MODULE.

5.2.13 EVENT LOG MODULE

In the EVENT LOG MODULE, the following event and unit characteristics are recorded in FILE LOGF for each unit that responds to a call:

- (1) event number;
- (2) time of call creation;
- (3) district location of the call;
- (4) the telecommunicator who interviewed the calling party;
- (5) the priority of the call;
- (6) the number of cars that responded;
- (7) the unit number;
- (8) the dispatch order of the unit, i.e. first, second, third, etc.;
- (9) the home district of the unit;
- (10) the pre-dispatch time; and
- (11) the total travel and service time.

This event log produces an itemized report of unit activity for the purpose of comparing the output of a simulation run to the actual activity for a particular shift. This module also terminates the patrol unit transaction.

5.2.14 PREVENTIVE PATROL MODULE

Every sixty seconds, the total number of available patrol units is calculated. A "count" statement performs the calculation for all patrol facilities and places the total in PARAMETER 10. A TABULATE statement then updates TABLE PREVPAT. The preventive patrol table is printed in the REPORT GENERATION MODULE.

5.2.15 SYSTEM CLOCK MODULE

The COPS model simulates an eight hour shift for the Monroe County Sheriff's Department. Because the focus is on a specific time period, rather than a particular number of events, a system clock module is included in the model. When eight hours have elapsed (28800 seconds), the clock module performs final statistical analysis.

First, cumulative travel and service time totals are converted into percentages. Employing indirect addressing (XL*P10), the module begins at the location of SAVEVALUE 21 and converts the intra-district response time into a percentage figure. The loop continues for inter-district response time (beginning at SAVEVALUE 41), as well as intra-district service time (beginning at SAVEVALUE 61) and inter-district service time (beginning at SAVEVALUE 81).

The simulation process then ends, and control passes to the REPORT GENERATION MODULE.

5.2.16 TRAINING MODULE

A primary value of simulation is its ability to create an environment in which training can be conducted. In the model COPS, the TRAINING MODULE provides this capability. The module provides a trainee with key information regarding each event. The trainee is prompted at each call for the unit which he/she would dispatch to the event in progress. The trainee's selection is then compared with the patrol unit which COPS has selected, either from historical data or as a result of the DISPATCH PLAN AND UNIT SELECTION MODULE. An agreement ratio is maintained throughout the training scenario. This ratio compares the number of unit selection matches between trainee and computer to the total number of dispatches.

The module begins by displaying the important characteristics of the next call-for-service in the screen format shown on the following page.

-----> CALL FOR SERVICE <-----

TIME OF CALL: *

CURRENT TIME: *

LOCATION: DISTRICT *

ADDRESS: *

EVENT TYPE: *

PRIORITY: *

NUMBER OF CARS FOR THIS CALL: *

YOU WILL BE DISPATCHING CAR NUMBER * (1, 2, 3, etc.)

THE FOLLOWING UNITS ARE AVAILABLE

DISTRICT: * UNIT: * PRIOR JOBS: * MOST RECENT CALL: *

CLEARED AT **: ** AFTER * MINUTES OF SERVICE

AT *****

TO REVIEW THE UNIT SUMMARY AGAIN, ENTER 000

TO MAKE A UNIT SELECTION, ENTER THE UNIT NUMBER

The screen is divided into two parts. The first section contains event information which remains on the screen. The remainder of the screen contains unit information which appears in boldface above. It is provided, in a scrolling window, for each available unit. At the conclusion of the unit data, the trainee may review the unit information again, or make a unit selection. When the trainee selects a unit for dispatch, the computer provides an acknowledgment message, or an error message with the correct unit. The trainee may then request information on the next call or may exit the training component.

The intent of displaying the unit data set forth above is to provide, for the dispatcher-trainee's consideration, information which is available under normal conditions. Therefore, although COPS does not use this data (most recent event type, event address, and previous unit-clearance and service times), the dispatcher requires this information to "re-create" the actual dispatching environment. Future versions of COPS should include these factors in the computer simulation process.

BLOCK DISP3 of the DISPATCH MODULE calls the TRAINING MODULE. Control is returned to BLOCK DISP4 of the calling module.

SECTION 6

SIMULATION RESULTS

6.1 INTRODUCTION

Two groups of tables are provided for each run of the simulation model. Ideas for the Resource Allocation tables and the Model Results tables are attributed to section VI of A Simulation Model Of Police Patrol Operations: Program Description, by Peter Kolesar, Warren E. Walker, and the New York City Rand Institute.

The Resource Allocation tables display data which informs the analyst of the input resources which were used to execute the model. These tables include DISTRICT ASSIGNMENTS, DISPATCH PLAN, and ENABLED SIMULATION MODULES.

The Model Results tables present information which the analyst can use to evaluate the allocation of a given set of resources. For each table in the Model Results group, a description of its format is provided, as well as an example of its output. The importance of the table for the analyst is then briefly discussed.

Appendix B displays complete output from a simulation run.

6.2 RESOURCE ALLOCATION TABLES

Three tables are provided for the analyst to understand the resources which were used in the model, and the degree of modelling which was performed.

6.2.1 DISTRICT ASSIGNMENTS

A two column table shows the number of units assigned to each district, as well as unit ids. The number of telecommunicators is also printed.

<u>UNIT DISTRICT</u>	<u>UNIT ID</u>
1	618
1	619
2	616

THERE ARE 8 TELECOMMUNICATORS ON DUTY.

6.2.2 DISPATCH PLAN

The dispatch plan contains an ordered list of police districts from which units were chosen for dispatch. The table displays the primary, secondary, tertiary, etc. districts for each police district.

DISTRICT DISPATCH PLAN

DISTRICT	FIRST RESPONSE	SECOND RESPONSE	THIRD RESPONSE	FOURTH RESPONSE	FIFTH RESPONSE	SIXTH RESPONSE	SEVENTH RESPONSE
B1:	B1	B2	B6	B4	B5	B7	B0
B2:	B2	B1	B6	B3	B4	B7	B0
B3:	B3	B2	B4	B6	B7	B0	B0
B4:	B4	B2	B1	B6	B5	B7	B0
B5:	B5	B4	B1	B7	B0	B0	B0
B6:	B6	B1	B2	B4	B7	B0	B0

6.2.3 ENABLED SIMULATION MODULES

A list of the modules selected by the analyst is provided. The event generation mode, i.e. historical or probabilistic, is also displayed.

ENABLED MODULE:	DISPATCH PLAN & UNIT SELECTION
ENABLED MODULES:	PRE-DISPATCH, TRAVEL, AND SERVICE TIMES
EVENT GENERATION MODE:	HISTORICAL

6.3 TABLES OF MODEL RESULTS

6.3.1 PATROL ACTIVITY

The activity of patrol units is displayed in the PATROL ACTIVITY table. For each unit, nine columns of information are provided for the analyst:

- Column 1 -- unit district;
- Column 2 -- unit id;
- Column 3 -- number of calls that the unit was assigned;
- Column 4 -- percentage of the shift that the unit was busy;
- Columns 5 & 7 -- percentage of time that the unit spent travelling and servicing calls within its home district;
- Columns 6 & 8 -- percentage of time that the unit spent travelling and servicing calls outside of its home district; and
- Column 9 -- average time that the unit spent in handling (travelling to and servicing) a call.

PATROL ACTIVITY

UNIT DIST	UNIT ID	# OF CALLS	BUSY % SHIFT	RESPONDING % IN % OUT		AT % IN	SCENE % OUT	AVERAGE TIME PER CALL(MIN)
1	618	10	56.74	12.26	3.12	32.69	8.67	27
1	619	8	55.47	4.83	8.35	11.97	30.32	33
2	616	9	55.51	10.42	4.17	28.73	12.19	30
2	617	9	57.75	10.42	4.89	27.95	14.50	31

The PATROL ACTIVITY table permits the analyst to examine the impact of resource allocation modifications on patrol workload and response time.

From a workload perspective, the distribution of events among district cars, the average time per call, and the comparison of job count to total unit utilization are available from this table.

The Patrol Activity table also allows the analyst to gain relevant information regarding the length and dispersion of police travel time. This is important for a number of reasons.

Since time spent travelling is time that cannot be spent performing preventive patrol, or engaging in community interaction, long response times should be avoided. Furthermore, long travel times increase the probability that officers will incur a vehicular accident, because of the nature of an emergency response to the scene of a call-for-service.

Lastly, if an officer is spending a disproportionate amount of time outside of his/her home district, it is likely that overall response to the public will be higher in those districts which suffer a high degree of "cross-district dispatch".

6.3.2 PRE-DISPATCH TIME

For each patrol district, the pre-dispatch time of the first car is displayed. This time is measured from the completion of the telecommunicator's activities to the initiation of the dispatch. Seven columns of information are presented:

- Call location -- zone or district level;
- Maximum number of calls that waited, at a given point in time, for the first unit to be dispatched;
- Average number of calls that waited at a given point in time;
- Total number of calls that were processed;
- Total number of calls that waited;
- Average wait time, in minutes, based on all calls;
- Average wait time, in minutes, based on the actual number of calls that waited.

PRE-DISPATCH TIME

-DISTRICT-	-MAX- NUM	-AVG- NUM	-TOTAL- CALLS	-WAITERS-	-AVG- TIME ALL (MIN)	-AVG- TIME WAITERS (MIN)
1	2	0	15	11	8.80	12.00
2	2	0	15	13	6.73	7.77
3	1	0	10	3	0.70	2.33

Pre-dispatch time statistics can be used by the analyst to review resource allocation schemes. In this respect, the intent is to minimize the delay in dispatching a call-for-service. This table provides a variety of measures which allow flexibility in the analysis of resource assignments. Thus, one analyst may desire to reduce the total number of calls that wait, while another analyst may accept a large number of "waiters", as long as the average wait-time for these calls is low.

6.3.3 DISTRICT RESPONSE TIME and SERVICE TIME

These tables provide aggregate information on the mean response time and mean service time of primary patrol units for each district. By definition, "primary patrol unit" is the first car to be dispatched to an event.

The RESPONSE TIME table displays the total number of calls which have been dispatched, the mean time, in minutes, of the primary unit, and the standard deviation for the mean vis a vis the collection of calls.

RESPONSE TIMES BY DISTRICT

-DISTRICT-	-CALLS-	-MEAN-	-STD. DEV-
1	19	6.84	1.07
2	16	7.38	1.15
3	18	7.00	1.03

The SERVICE TIME table presents the same format for the average district service time.

These tables can be used by the analyst to gain another measure of the "police response". While the PRE-DISPATCH TIME table provides information on the length of time that a call waits for dispatch, the RESPONSE TIME table displays the average time that a caller waits for the primary unit to arrive. The SERVICE TIME table shows the average amount of time that the primary unit spends upon arrival at the scene.

6.3.4 PREVENTIVE PATROL

The PREVENTIVE PATROL table provides the analyst with the number of units which engaged in preventive patrol at any given moment of the shift. The model scans the status of all patrol units every minute and records the number of available units in the table. When the table is printed, this data is presented in three columns:

- Column 1 -- the number of units which were engaging in preventive patrol;
- Column 2 -- the percentage of the total time that X (column 1) units were patrolling; and
- Column 3 -- the percentage of the total time that more than X (column 1) units were conducting preventive patrol.

PREVENTIVE PATROL

NUMBER OF CARS	PERCENTAGE OF TIME	MORE THEN COLUMN 1 CARS
0	6.05	93.95
1	9.19	84.76
2	11.90	72.86
3	15.66	57.20

The analyst can use this table to measure the impact of resource allocation changes on the number of units which are conducting preventive patrol at a given point in time. It is especially useful if one of the goals of the police department is to insure that a guaranteed number of units is available for responding to high priority calls or for performing specialized patrol activities.

6.4 GRAPHS

Some of the key information is summarized in graph form for illustrative purposes. Two graphs are illustrated in Appendix B.

Graph 1 displays the number of events handled by district cars.

Graph 2 presents the average primary unit pre-dispatch time for events, by district and zone.

6.5 ANALYSIS OF SAMPLE DATA

This section applies the preceding discussion to actual data. On the following pages, the reader will find a comparison of the different runs of the model. Run # 100 simulates a six district - ten unit scenario. Run # 200 maintains the district and unit configuration, but modifies the order of the dispatch plan. No cross-district dispatching is permitted. Thus, if a unit is not available for a call in its home district, the call waits. Run # 300 returns to the dispatch plan of Run # 100, but assigns only eight patrol units to six districts.

SIMULATION MODEL

RUN #100

RESOURCES:

UNIT DEPLOYMENT:

DISTRICT 1:	618	619
DISTRICT 2:	616	617
DISTRICT 3:	627	628 629
DISTRICT 4:	623	
DISTRICT 5:	621	
DISTRICT 6:	626	

DISPATCH PLAN:

DISTRICT 1:	1	2	6	4	5	7
DISTRICT 2:	2	1	6	3	4	7
DISTRICT 3:	3	2	4	6	7	
DISTRICT 4:	4	2	1	6	5	7
DISTRICT 5:	5	4	1	7		
DISTRICT 6:	6	1	2	4	7	

PATROL CAR UTILIZATION FOR SHIFT:

MEAN	42.18%	BUSY
STANDARD DEVIATION	15.60	
RANGE	27.35 - 65.92%	BUSY

AVERAGE % OF TIME SPENT TRAVELLING TO AND SERVING EVENTS:

IN HOME DISTRICT	63%
OUTSIDE OF HOME DISTRICT	37%

AVERAGE ZONE PRE-DISPATCH TIME FOR ALL EVENTS:	3.15 MIN
AVERAGE ZONE RESPONSE TIME OF PRIMARY UNITS:	7.45 MIN
AVERAGE ZONE SERVICE TIME OF PRIMARY UNITS:	24.68 MIN
AVERAGE NUMBER OF UNITS ENGAGING IN PREVENTIVE PATROL	6

SIMULATION MODEL

RUN #200

RESOURCES:

UNIT DEPLOYMENT: DISTRICT 1: 618 619
 DISTRICT 2: 616 617
 DISTRICT 3: 627 628 629
 DISTRICT 4: 623
 DISTRICT 5: 621
 DISTRICT 6: 626

DISPATCH PLAN:

DISTRICT 1: 1
DISTRICT 2: 2
DISTRICT 3: 3
DISTRICT 4: 4
DISTRICT 5: 5
DISTRICT 6: 6

PATROL CAR UTILIZATION FOR SHIFT:

MEAN	39.73%	BUSY
STANDARD DEVIATION	21.25	
RANGE	0 - 68.49%	BUSY

AVERAGE % OF TIME SPENT TRAVELLING TO AND SERVING EVENTS:

IN HOME DISTRICT	100%
OUTSIDE OF HOME DISTRICT	0%

AVERAGE ZONE PRE-DISPATCH TIME FOR ALL EVENTS:	12.60 MIN
AVERAGE ZONE RESPONSE TIME OF PRIMARY UNITS:	7.62 MIN
AVERAGE ZONE SERVICE TIME OF PRIMARY UNITS:	24.64 MIN
AVERAGE NUMBER OF UNITS ENGAGING IN PREVENTIVE PATROL	6

SIMULATION MODEL

RUN #300

RESOURCES:

UNIT DEPLOYMENT:

DISTRICT 1:	618
DISTRICT 2:	616 617
DISTRICT 3:	627 628
DISTRICT 4:	623
DISTRICT 5:	621
DISTRICT 6:	626

DISPATCH PLAN:

DISTRICT 1:	1	2	6	4	5	7
DISTRICT 2:	2	1	6	3	4	7
DISTRICT 3:	3	2	4	6	7	
DISTRICT 4:	4	2	1	6	5	7
DISTRICT 5:	5	4	1	7		
DISTRICT 6:	6	1	2	4	7	

PATROL CAR UTILIZATION FOR SHIFT:

MEAN	52.39%	BUSY
STANDARD DEVIATION	14.81	
RANGE	39.05 - 73.85%	BUSY

AVERAGE % OF TIME SPENT TRAVELLING TO AND SERVING EVENTS:

IN HOME DISTRICT	48%
OUTSIDE OF HOME DISTRICT	52%

AVERAGE ZONE PRE-DISPATCH TIME FOR ALL EVENTS: 3.96 MIN

AVERAGE ZONE RESPONSE TIME OF PRIMARY UNITS: 7.50 MIN

AVERAGE ZONE SERVICE TIME OF PRIMARY UNITS: 24.68 MIN

AVERAGE NUMBER OF UNITS ENGAGING
IN PREVENTIVE PATROL 4

After reviewing the results of the simulation runs, several points can be stated. The average patrol car utilization for a shift is predictably higher in Run # 300 where a smaller number of patrol units must handle the same number of calls as in the two preceding runs. The mean shift utilization for Run # 100 is higher than in Run # 200. This can be traced to the fact that patrol units in Run # 100 respond to adjoining districts when needed.

The average percentage of time spent travelling to events and servicing events within a unit's home district is 100% in Run # 200 where units respond only to events which originate in the units' home districts. Run # 100 shows that units stay within their home district more than units in Run # 300. This difference can be attributed to the fact that Run # 100 has more units to respond within a district. Thus, less cross-district dispatching occurs.

Differences between average zone pre-dispatch times can also be logically explained. Run # 200 maintains the longest wait time for events because of the restrictive dispatch plan. Therefore, even though ten units are available, as in Run # 100, they are prevented from servicing calls if the calls originate in a district other than their own.

Lastly, an average of six units engaged in preventive patrol during the shift in Runs # 100 and 200. This information may help a police manager reconsider the "no cross-dispatch" policy if, in fact, it was intended to guarantee a minimum number of cars engaging in preventive patrol. Run # 300 displays an average of four patrol units available for patrol during the shift.

SECTION 7

VALIDATION

7.1 VALIDATION STRATEGY

7.1.1 INTRODUCTION

Validation of a simulation model is the process of determining the extent to which the model predicts the performance of the system under study. One way to validate a model is to ascertain the "[d]egree to which [the] model duplicates past system behavior using historical input data".¹²

In an attempt to validate COPS, a computer program was written to gather historical data, from the computer-aided dispatch system (CAD). In addition, programs were developed on CAD to calculate workload and waiting-line statistics for patrol units. These CAD statistics were compared to the results of the simulation model when historical event data was used as input to the model. Section 7.1.2 discusses the development of a "benchmark" version of the simulation model which utilizes historical data.

Section 7.1.3 then presents three versions of the simulation model. Starting from total historical inputs (the benchmark), the three versions gradually substitute a probabilistic approach to the calculation of data as a progressive way of assessing the effect of critical modules.

Section 7.1.4 discusses the mathematical formula and computer programs which were used to determine if the results of these versions of the simulation model replicated the behavior of the actual system.¹³

It is important to remember that the COPS model was designed as an academic thesis. It does not purport to be a validated model for actual use. In this regard, the reader should reference Section 8 which addresses "Future Areas of Research". A validation approach, rather than conclusive validation results, is therefore presented.

7.1.2 BENCHMARK CONSTRUCTION

The first step in validating COPS was to develop a version of the model which mirrored the live system. This version, called a benchmark, used historical input data to replicate system behavior.

A program was executed on the CAD system to extract the following data from each event that occurred in Zone B between the hours of 2 PM and 10 PM for any desired day:

- (1) call creation time;
- (2) location of the call;
- (3) priority of each call;
- (4) total number of cars that were dispatched to the call;
- (5) actual units which were dispatched to each call for service, including cancelled units and preempted units;
- (6) pre-dispatch time for each unit;
- (7) travel time for each unit; and
- (8) service time for each unit.

This data was then read from a file into COPS. The modules of the COPS model were modified to accept this data without independently calculating any event or unit characteristics. Probabilistic simulation modules were disabled in order that facility and queue statistics could be generated using historical data.

Data analysis programs were run on the CAD system to produce unit workload (facility) and waiting line (queue) statistics using the same historical data as outlined above. Facility and queue statistics from CAD and COPS were then compared. The COPS model was fine-tuned until all exceptions between CAD output and COPS output were resolved. The benchmark version of COPS continued to be used throughout model development to insure that the logical flow of event transactions remained consistent.

In summary form, the benchmark process consists of the following steps:

- (1) Extract historical event and unit data from CAD.
- (2) Transfer CAD data into the COPS model "events" file.
- (3) Run the historical version of the COPS simulation model.
- (4) Execute the programs set forth in Section 7.2 with CAD data to obtain workload and waiting-line statistics. This data corresponds to the facility and queue statistics generated by COPS.
- (5) Compare the output from step 4 above to the facility and queue statistics of COPS.
- (6) Modify COPS until all exceptions are removed.

7.1.3 SIMULATION MODEL VERSIONS

After construction of a benchmark which replicated live system activity, selected probabilistic COPS modules were enabled. For example, the DISPATCH PLAN AND UNIT SELECTION module was activated for a particular run of the model. This meant that COPS would use actual event location, event priority, number of cars, and all historical times -- creation, pre-dispatch, travel and service. However, it was the model's responsibility to select the correct units. By beginning from a benchmark foundation, the logic of individual modules could be tested.

Table 7.1 displays key characteristics of each version of the model. As the reader will note, the benchmark version obtains all of its inputs from historical data. Version 1 utilizes the model to calculate the manner in which units are selected for dispatch. Version 2 employs the model in calculating all unit times, as well as selecting all units. Version 3 is a totally probabilistic-driven model. In addition to the characteristics of Version 2, Version 3 determines the frequency of calls-for-service by using an exponential function.

TABLE 7.1
CHARACTERISTICS OF SIMULATION MODEL VERSIONS

	<u>BENCHMARK</u>	<u>VERSION 1</u>	<u>VERSION 2</u>	<u>VERSION 3</u>
--	------------------	------------------	------------------	------------------

<u>event generation</u>	historical	historical	historical	model
<u>calculation of times</u>	historical	historical	model	model
<u>unit selection method</u>	historical	model	model	model

7.1.4 VALIDATION PLAN

The next step was to compare the results of the three versions of the model with actual patrol unit workload. The mean daily number of dispatches for each patrol unit in a one month period was calculated. The number of dispatches that the unit handled under each of the simulation versions was then compared with the unit's daily historical mean.

In comparing simulation and historical data, an isomorphic relationship did not materialize. For this reason, a confidence interval was established for the historical mean. A confidence interval implies that the limits of the interval contain the mean of the data set, given a certain level of confidence.¹⁴ The version results were again compared to the confidence intervals to determine if, in fact, the dispatch load for each unit fell within the intervals.

Two questions should be answered in relation to this strategy. First, what is the given "level of confidence"? Second, why was the t distribution used for calculating the low and high bounds of the interval?

The level of confidence, or confidence coefficient, is the "probability that correct interval estimates are obtained".¹⁵ Although the goal is to have a very small interval, "the confidence coefficient can only be increased by increasing the width of the confidence interval".¹⁶ This inverse relationship means that a 99% confidence interval is actually less precise than a 90% confidence interval. A tradeoff between risk and accuracy is present. To minimize the risk of receiving an incorrect interval, this author selected a 99.9% confidence coefficient for comparison of simulation results to historical results.

The choice of the t distribution was made because of its ability to approximate distributions that are normal or slightly skewed.¹⁷ The formula for determining the confidence interval is as follows:

Lower limit = mean - $t(1 - \alpha/2; n-1) * (\text{std. deviation} \div \text{square root of the sample size})$

Upper limit = mean + $t(1 - \alpha/2; n-1) * (\text{std. deviation} \div \text{square root of the sample size})$

where:

$(1 - \alpha)$ = desired confidence level (e.g. 90%, 95%, 99%)

n = sample size;

$(1 - \alpha/2)$ = percentile of the t distribution;

$(n - 1)$ = degrees of freedom;

The expression $t(1 - \alpha/2; n-1)$ represents the parameters that are used to obtain the appropriate value from a table of the percentiles of the t distribution. For example, assume that the mean of a data set is 8.94, the sample size is 31, the standard deviation is 3.78, and the desired confidence coefficient is 99.9% ($1 - \alpha = .999$). The expression evaluates as follows:

Lower limit = $8.94 - t(1-.001/2; 31-1) * (3.78 \div \sqrt{31}) =$

$8.94 - t(.9995; 30) * (.679) =$

$8.94 - (3.646) * (.679) = \underline{6.46}$

Upper limit = $8.94 + (3.646) * (.679) = \underline{11.42}$

Four computer programs were written on the computer-aided dispatch system to implement the strategy outlined above:

CONF1.PAS extracts the required fields of data from the master event file.

CONF2.PAS accepts a file of records extracted by CONF1.PAS, and sorted on day of month, unit district, and unit id. CONF2.PAS counts the total number of events for each unit for each day of the month. A file of records is then produced for statistical analysis. The records contain unit id and number of events.

CONF3.PAS accepts the records from CONF2.PAS after they have been sorted on unit id. The sum, sample size, mean, and standard deviation are determined and written to a file.

CONF4.PAS is an interactive program that requests the mean, standard deviation, sample size, confidence coefficient, and t distribution value. It then provides the corresponding confidence interval.

TABLE 7.2
SIMULATION COMPARISONS
DISPATCHES PER UNIT
SHIFT MEAN

<u>UNIT</u>	<u>CONFIDENCE INTERVAL</u>	<u>HISTORICAL</u>	<u>VERSION 1</u>	<u>VERSION 2</u>	<u>VERSION 3</u>
618	6.46 -11.42	10	5	8	10
619	5.96 - 9.84	3	7	8	9
616	6.98 -12.08	8	17	8	8
617	5.80 -10.52	8	6	7	8
627	6.31 -11.81	11	6	5	5
628	3.76 - 7.98	3	11	6	5
629	3.79 - 8.33	7	4	5	5
623	3.80 - 7.00	4	4	4	4
621	2.67 - 5.59	2	6	5	4
SUP	2.20 - 4.68	1	1	3	5

Table 7.2 compares the number of events that each unit handled in a shift under different versions of the model. Numbers which fall within the 99.9% confidence interval have been highlighted.

Six of the ten units in the Historical column lie within the confidence interval. The remaining four have a total absolute difference of 5.59 events.

Only four of the units in Version 1 agree with the confidence interval. This version used historical events and times, but allowed the model to select units. The low agreement ratio may be due to the logic of the run, i.e. the times are not realistic for the units selected.

Version 2 used historical events, but obtained pre-dispatch, travel, and service times from the model. Workload figures for nine of the ten units lie in the 99.9% confidence interval. The total absolute difference is 1.31 events.

Version 3 generated events from the interarrival means in the model. Furthermore, all times and units were determined by the model. Workload figures for eight of the ten units lie in the confidence interval. The absolute difference is 1.63 events.

The preceding discussion is not intended to prove that the model is validated. It does, however, show a high degree of agreement with the 99.9% confidence level that was established from an examination of a thirty-one day period of activity.

7.2 CAD BENCHMARK EVALUATION PROGRAMS

Two programs were run on the CAD system to verify the results obtained from the benchmark version of the simulation model. An outline of the WAITING LINE STATISTICS and PATROL CAR ACTIVITY programs follows. Appendix C displays sample output.

7.2.1 WAITING LINE STATISTICS

This program accepts a sorted file of records and produces statistics relating to time delay between call receipt and dispatch of the first vehicle.

INPUT/OUTPUT INFORMATION

INPUT RECORD

- Call District
- Dispatch Time
- Call Received

OUTPUT

- Waiting Line Statistics

MODULES

MAIN:

While time of call receipt or current time is greater than 2:00 pm and less than 10:00 pm,
then:

- check for presence of waiting condition (STAGE1)
- check for end of waiting condition (STAGE2)

STAGE1:

If receive time is less than dispatch time, then:

- increment wait count
- increment cumulative wait time
- place dispatch time on queue
- compare current number of waiting calls to maximum number of waiting calls
- if current is greater than maximum, increment maximum

STAGE2:

If the queue contains dispatch times then

- compare the current time to each queue entry

If the dispatch time equals the current time then

- decrement the number of waiting calls
- remove the dispatch time from the queue

STATS:

At the conclusion of the program, print the following statistics:

- maximum number of calls that waited at one time
- total number of calls received
- total number of calls that waited
- average wait time of all calls
- average wait time of calls that waited

7.2.2 PATROL CAR ACTIVITY

This program accepts a sorted file of records and produces statistics relating to the activity of each patrol unit.

INPUT/OUTPUT INFORMATION

INPUT RECORD

Call District
Unit ID
Unit District
Call Priority
Travel Time
Service Time

OUTPUT

Patrol Car Activity Statistics

MODULES

MAIN:

Read a record

If the patrol unit id equals the previous unit id then call

Record_Workload

- increment the number of calls handled by this unit
- add the unit's travel time to the existing cumulative travel time
- add the unit's service time to the existing cumulative service time

Else calculate and print statistics (STATS)

STATS:

At the conclusion of the program, print the following statistics:

- unit district
- unit id
- number of calls handled by the unit
- % of time that the unit was busy
- % of time that the unit responded to calls within and outside of its assigned district
- % of time that the unit serviced calls within and outside of its assigned district
- average time spent per call

SECTION 8

CONCLUSIONS

8.1 INTRODUCTION

The COuntywide Police Simulation System was developed as an academic thesis project for the purpose of modelling the delivery of police services. The success of the endeavor should be evaluated from two perspectives:

- (1) the ability of the model to simulate
 - (a) the processing of calls by a public safety communications center; and
 - (b) the associated response of law enforcement officers to events requiring police assistance; and
- (2) the utility of the model as a training system for police dispatchers.

8.2 THE OPERATIONAL PERSPECTIVE

From the first viewpoint, this writer believes that COPS can be considered to have achieved its goals in a panoramic sense. The validation results presented in Section 7, while not exhaustive or conclusive, provide an indication that the model generally parallels the actual delivery of police services. Without any doubt, there is the need for additional efforts at validating the COPS model if, in fact, the model is to be used by police managers.

In addition to validation concerns, several topics can be identified which require further attention. Section 8.4 discusses data collection and programming issues which will improve the model. Of greater importance, however, are those areas which cannot be realistically affected and, therefore, would preclude the model from being validated. Two of these areas are (1) the inability of dispatchers to determine the actual location of police officers at a given point in time, and (2) the absence of an absolute reporting mechanism for the arrival and clearance of police units.

The most elusive issue is the dispatcher's inability to determine where an officer is patrolling when the officer is not assigned to a call-for-service. For the majority of an officer's shift, he/she is not under direct supervision by police managers. Furthermore, there is currently no automatic vehicle location system in Monroe County. As a result, the dispatcher must rely on the information which the officer provides as to his/her current activity and location.

It is a fact that officers often cross district boundaries to assist other patrol officers. If the dispatcher is not advised of this situation, the next call-for-service in the officer's home district may, indeed, result in a longer response time than anticipated. The dispatcher's decision would have been made on incomplete and inaccurate information. To the extent that this practice continues, the model will be prevented from achieving a pure state.

In addition to the uncertainty associated with officer location, validation attempts are inhibited by the lack of a consistent audit trail of officer activity. A dispatcher may simultaneously provide an officer with several calls. Upon completion of all the calls, the officer reports back to the dispatcher with disposition information on each call. This practice removes the ability to capture travel and service times for each individual event.

Political considerations also limit the ability to build a model which simulates a rational system. Police officers may be dispatched to events because the community believes they should be dispatched, not because police service is truly required. As a result, officers will form an internal priority structure for responding to these calls. Variation in this informal prioritization scheme will prevent consistent delivery of police services and, consequently, frustrate attempts at designing a valid model.

As an example, deputies are dispatched to every emergency medical service call. The intent is for the deputy to determine if any injuries are indicative of a criminal act, e.g. an assault. In actuality, many deputies receive the ambulance call from the dispatcher and postpone any action until such time that the deputy is near the ambulance corps facility. The deputy then reviews the report of the ambulance technicians and prepares the police report. The intent of the dispatch is undermined, travel and service times are meaningless, and the officer is unnecessarily removed from preventive patrol or dispatch to other calls-for-service.

8.3 THE TRAINING PERSPECTIVE

Unlike the operational frame-of-reference discussed above, the model may be used as a training aid without the need for extensive validation efforts. In the historical training mode, the model mirrors actual experience. A one-to-one relationship can, therefore, be easily established.

Like the operational use of the model, COPS can be considered a success from this training perspective. The true value of the training version of the model lies in the ability of the analyst to compare the performance of trainees with each other, rather than to compare the trainee with the computer. The system awards a score to a trainee based upon the trainee's skill at selecting units that were, in fact, dispatched under live operating conditions. By evaluating the variation of scores among dispatchers, the model can be used to highlight gross differences in dispatching judgment.

For example, assume that the majority of dispatchers, using the training version of the model, achieved a high percentage of agreement with each other. Attention should then be focused on the few dispatchers who received a significantly smaller number of correct answers. In a similar sense, the simulation model could also be used as a progress test for new dispatchers. By establishing an acceptable "agreement" range, dispatcher trainees could be compared to more experienced dispatchers.

8.4 FUTURE AREAS OF RESEARCH

The COuntywide Police Simulation system does not purport to be the conclusive simulation model for police patrol activity. Indeed, as previously mentioned, there are a number of areas which this author feels are worthy of enhancement.

PREEMPT MODULE

The practice of preempting cars for higher priority calls should be addressed, as well as the practice of holding calls for certain units. The final version of COPS considered preemptions and call-holding as part of the historical data flow. However, the probabilistic event generation component does not address these two factors.

EVENT GENERATION

The analyst should be able to enter the number of events which are expected within a given shift. The model should then calculate the interarrival mean for the several GENERATE blocks.

The analyst should also be able to define the composition of the calls-for-service. For example, the percentage of the workload which requires a priority-one response should be under the control of the analyst without having to modify the software.

LOCATION

A finer level of granularity should be incorporated into the model wherever locations are referenced, e.g. in the unit selection and travel time modules. The author believes that a greater degree of precision in relation to the location of units and calls-for-service would yield more accurate results.

EVENT TYPE

The concept of "event type" should be included in the simulation model. There are often certain decisions (e.g. travel time, number of units, dispatcher activities) which are more related to the type of call-for-service than to the priority of the call.

For example, a motor vehicle accident may require the dispatcher to contact a tow truck, a traffic stop involves a license check, and a driving-while-intoxicated arrest requires a family notification. These dispatcher actions are related to the type of call, rather than the priority of the call. Furthermore, a call may be classified as priority two; however, it may require several cars or an urgent response.

DATA COLLECTION

Computer programs which collect time-related data record hours and minutes. Future efforts should include the collection of seconds.

TRAVEL AND SERVICE TIMES

Travel and service times are currently represented by constant data values. Attention should focus on the use of functions to represent these values. If travel and service times are subject to hourly fluctuations, then this variable must also be factored into the model.

MULTI-AGENCY DISPATCHERS

The dispatcher who handles Zone B Sheriff's cars also dispatches patrol units from Zone A and the East Rochester Police Department. The model should recognize this fact, as pre-dispatch time should decrease if the dispatcher's attention is not divided among several zones or agencies.

In addition, dispatchers who control several different groups of units are more likely to cross-dispatch units. Zone A cars will assist Zone B units and vice versa. This fact, in effect, creates a larger pool of vehicles which can be scanned for unit selection purposes.

OPTIONAL DISPATCHES

In some cases, several cars are dispatched to a scene when, in fact, less than the ideal number is actually needed. A call may routinely require three cars, but be successfully handled with two units if a third unit is not readily available. How should the model reflect this logic? This concept of "optional dispatch" should be examined in more detail.

AVAILABLE UNITS

The pool of available units should be expanded to include special units, such as traffic units or technical units. Special units handle calls only under special circumstances, e.g. if a call has waited for an unusually long period of time or a crime is reported in-progress.

POST-CLEARANCE TRAVEL TIME

COPS makes the simplified assumption that units who are dispatched into adjoining districts are immediately re-located in their home district upon clearance of the call. In fact, this is not the case. Consideration must therefore be given to the time police officers spend travelling back to their home district after clearance from an inter-district dispatch.

NON-EVENTS

Officers spend time on administrative and personal duties, like court duty, lunch breaks, and departmental meetings. Out-of-service time should be analyzed and treated as an event because it removes officers from assignment to calls-for-service.

PRIMARY UNIT STATUS

The first unit to be dispatched is classified as the primary unit in the COPS model. In reality, this designation may change during the progress of the call. Because COPS uses the concept of "primary unit" in determining service time and in calculating statistics, consideration should be given to a dynamic definition of primary status.

DUPLICATE AND ADMINISTRATIVE CALLS

Telecommunicator service time has been defined as a function of the type of call, i.e. central-dispatch police call, agency-transfer police call, fire call, and emergency medical services call. A fifth call type must be added to this list to account for calls which do not require dispatch of a public safety agency.

Callers notifying the communications center of an event which has previously been reported necessitate an abbreviated interview with no subsequent event entry. Likewise, administrative calls do not require a formal interview. The COPS model did not include this type of call in determining telecommunicator service time because this data is not currently recorded for data processing purposes. However, this classification of call is important, for it represents a drain on telecommunicators' time and, therefore, should be factored into the model.

BUSY STATE LOGIC

The COPS model begins with no telecommunicator or dispatcher activity. In actuality, calls and events do not respect time boundaries. Therefore, when a shift commences, there is a certain level of activity already in progress. This is more controlled for police officers because lower priority calls which occur at the end of a shift are generally held until the new shift begins. However, telecommunicators cannot schedule their workload.

The model should run through a shift of activity prior to the recording of any statistics.

8.5 SUMMARY

Section 8 discussed the relative success of the COuntywide Police Simulation system from operational and training perspectives.

From the first point-of-view, the model can be considered successful in a global sense. However, the need for further validation efforts cannot be overemphasized. In addition, the current style of policing hides certain critical information from the view of the dispatcher and, therefore, the analyst who wishes to design a model. Section 8.4 highlighted data collection and programming issues which are able to be addressed. By including these considerations in future model development, the COPS model will be significantly improved.

From the second perspective, the model can serve as a valuable training tool for police dispatchers. Dispatching, like policing, demands that the life-critical nature of the operation be disturbed as little as possible. The COPS model adds a dimension to the training program that cannot be duplicated in the classroom or by simple observation of other dispatchers.

FOOTNOTES

¹ Herbert H. Isaacs, "A Study of Communications, Crimes and Arrests in a Metropolitan Police Department," Task Force Report: Science and Technology (Washington, D.C.: U.S. Government Printing Office, 1967), p. 100.

² Tony Pate, Amy Ferrara, Robert A. Bowers, and Jon Lorence, Police Response Time - Its Determinants and Effects (Washington, D.C.: Police Foundation, 1976), pp. 48-49.

³ 1987 Monroe County Directory, prepared by the Monroe County Office of Public Information (Rochester, New York, 1987), pp. 46-47.

⁴ P.A. Bobillier, B.C. Kahan, and A.R. Probst, Simulation with GPSS and GPSS V (New Jersey: Prentice-Hall, Inc., 1976), pp. 4-17.

⁵ John Neter, William Wasserman, and G. A. Whitmore, Applied Statistics (Boston: Allyn and Bacon, Inc., 1978), p. 157.

⁶ Ibid., pp. 141-142.

⁷ Ibid., p. 157.

⁸ Bobillier, Simulation with GPSS and GPSS V, pp. 155-156.

⁹ Wolverine Software Corporation, :CHECKPOINT Newsletter, Volume 3, Number 1 (Winter 1987), p.2.

¹⁰ Bobillier, Simulation with GPSS and GPSS V, pp. 155-156.

¹¹ Ibid., pp. 155-156.

¹² William C. House, editor, Business Simulation for Decision Making (New York: Petrocelli, 1977), p. 60.

¹³ Neter, Applied Statistics, pp. 246-247.

¹⁴ Ibid., p. 241.

¹⁵ Ibid., p. 240.

¹⁶ Ibid., pp. 243-244.

¹⁷ Ibid., p. 247.

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APPENDICES

APPENDIX A - DATA COLLECTION OUTPUT

APPENDIX B - SAMPLE MODEL OUTPUT

APPENDIX C - BENCHMARK EVALUATION TABLES

APPENDIX D - BLOCK DIAGRAMS

APPENDIX A
DATA COLLECTION OUTPUT

HISTORICAL EVENT GENERATION

EVENT	TIME	LOC	PRIORITY	CARS	UNIT	DIST	PRE-DISP	SERVICE	ONSITE	CODE
1	240	B01	2	1	616	B02	1080	1620	FALSE	01
					623	B04	0	3480	TRUE	35
2	1260	B04	1	2	623	B04	4080	1020	TRUE	40
3	1800	B02	1	1	618	B01	60	2220	FALSE	02
4	1980	B03	2	1	627	B03	60	3240	FALSE	01
5	2700	B02	2	1	617	B02	60	7020	FALSE	09
6	3480	B05	1	1	621	B05	180	1080	FALSE	30
7	3780	B01	3	1	618	B01	300	600	FALSE	42
8	4200	B02	2	1	616	B02	60	2100	FALSE	44
9	4500	B03	3	2	629	B03	120	420	FALSE	34
					628	B03	420	120	FALSE	30
10	4560	B01	1	2	628	B03	60	240	FALSE	35
					618	B01	360	4020	FALSE	09
11	4680	B01	1	2	619	B01	0	60	TRUE	35
					619	B01	120	0	TRUE	47
12	4740	B04	2	1	623	B04	0	180	TRUE	40
13	6420	B03	2	3	629	B03	0	3600	TRUE	40
					627	B03	2280	60	TRUE	35
14	8760	B01	2	3	627	B03	3420	180	TRUE	34
15	8760	B03	1	1	618	B01	1320	0	FALSE	35
					616	B02	1320	660	FALSE	35
16					618	B01	2040	0	FALSE	40
17					627	B03	0	720	TRUE	25

CONTENTS OF FILE EVENTSF

240 1 2 1 616 1080 1620 01
 1260 4 1 2 623 0 3480 35 623 4080 1020 40
 1800 2 1 1 618 60 2220 02
 1980 3 2 1 627 60 3240 01
 2700 2 2 1 617 60 7020 09
 3480 5 1 1 621 180 1080 30
 3780 1 3 1 618 300 600 42
 4200 2 2 1 616 60 2100 44
 4500 3 3 2 629 120 420 34 628 420 120 30
 4560 1 1 2 628 60 240 35 618 360 4020 09
 4680 1 1 2 619 0 60 35 619 120 0 47
 4740 4 2 1 623 0 180 40
 6420 3 2 3 629 0 3600 40 627 2280 60 35 627 3420 180 34
 8760 1 2 3 618 1320 0 35 616 1320 660 35 618 2040 0 40
 8760 3 1 1 627 0 720 25
 10260 3 3 1 627 0 0 22
 10560 5 2 1 616 240 2880 40
 10620 2 2 3 616 120 60 35 937 2580 2580 35 937 9600 0 04
 10620 1 2 1 617 300 1200 40
 12900 7 1 2 627 240 60 35 629 300 660 30
 12960 2 2 2 617 180 60 35 619 240 12720 06
 13560 2 1 2 616 180 0 35 618 180 180 42
 13980 1 2 1 618 120 1380 02
 15000 3 3 1 629 0 900 40
 15420 3 1 2 627 0 2580 34 628 120 2460 02
 15600 3 2 1 629 360 3180 09
 16020 5 1 1 616 60 540 40
 17760 2 3 1 617 0 1080 46
 19860 2 1 3 616 60 60 35 618 120 3900 09 617 120 3900 34
 20520 1 2 1 618 3900 2340 01
 21600 3 2 2 627 180 2220 35 627 2940 0 30
 23700 2 1 4 623 120 60 35 618 180 540 34 617 180 540 42 610 360 300 34
 23760 3 1 2 629 0 660 35 627 240 540 15
 25320 3 2 1 629 240 1920 40
 25560 2 1 2 617 0 480 35 621 60 840 15
 25800 1 2 1 617 240 660 40
 27960 3 1 1 627 0 720 47
 28080 5 3 1 621 1560 840 42

CONTENTS OF FILE ADDRESSF

'3195 BRIGHTON HENRTA T L RD (HEN)/ HOLIDAY HEALTH
'RT390 @ COUNTY TURN AROUND;EYE RUN
'HYLAN DR @ JEFFERSON RD FRONT ON CHASE PITKIN (HEN)/
'24 SCOTT LA (CHI)/
'601 ELMWOOD AV (HEN)/HILTON INN ON THE CAMPUS
'26 MENDON-IONIA RD (MEN)/ST CATHERINE'S CHURCH
'140 HOLLYBROOK RD (HEN)/
'2059 BRIGHTON HENRTA T L RD (HEN)/KELLS MARINE
'W ON CHILI AV @ STOTTLE RD (CHI) /<3602 @ 1> /
'STONE RD @ PINNACLE RD (HEN) /<1 @ 290> /CHESTNUT HILL CONTRUC SITE
'CAMLOT @ SOUTH
'RT390 @ EXIT 11
'JACKLYN DR @ FISHER RD (CHI) /<0 @ 320> /
'E RIVER RD @ THRUWAY (HEN) /<5066 @ 3650> /
'PAUL RD;/BY AIRPORT
'ROUTE 390 @ SCOTTSVILLE RD
'ROUTE 251 @ ROUTE 64 (MEN) /<1 @ 1> /
'93 ROSELAWN AV (FRP)/
'6 GATE HOUSE TR (HEN)/
'ROUTE 490 N/B @ WEGMAN RD (GAT) /<1161 @ 650> /IN REAR OF GATES CHILI SCHO'
'3440 W HENRIETTA RD (HEN)/ SEAR'S/MERCHANDISE P/U ENTR
'SOUTHTOWN PLAZA ; 3333 W HENRIETTA RD (HEN)/MONROE SAVINGS BANK
'6 GATE HOUSE TR (HEN)/
'ROUTE 490 @ CHILI CENTER/W-B BET CHILI CENTER AND CHILI
'ROUTE 252 @ ROUTE 386 (CHI) /<325 @ 96> /
'9 GRENELL DR (CHI)/
'467 BOUGHTON HILL RD (MEN)/
'186 COUNTESS DR (HEN)/
'136 JOHN ST (HEN)/
'72 HIGH MANOR DR (HEN)/ APT 7
'CHILI-PAUL PLAZA ; 3240 CHILI AV (CHI)/IN FIELD BEHIND K-MART
'171 CLAY RD (HEN)/NATIONAL WAREHOUSE
'3880 UNION ST (CHI)/ ACROSS FROM
'29 OMEGA DR (CHI)/
'18 OVERLAND TR (HEN)/
'32 BRENDAN CI (HEN)/
'390 @ BROOKS/IWX334
'448 LANNING RD (MEN)/

CONTENTS OF FILE CALLSF

'LARCB'
'MISCA'
'MVAA '
'BURGB'
'MISCB'
'SUSPA'
'ASSTB'
'FORGB'
'ANOYB'
'MISCA'
'TSTOB'
'MISCB'
'MISCB'
'ASSTB'
'SUSPA'
'ASSTB'
'CKWLA'
'MSPRB'
'MVAB '
'DCONA'
'LARCB'
'ASSTA'
'MVAB '
'ASSTB'
'MVAA '
'MSPRB'
'FIREA'
'WARRB'
'SUSPA'
'LARCB'
'MSPRB'
'SUSPA'
'ALRMA'
'CRMSB'
'ALRMA'
'MISCB'
'TSTPB'
'ANOYB'

PROBABILISTIC EVENT GENERATION

INTERARRIVAL MEANS FOR CALLS ARRIVING AT THE 911 CENTER BY CATEGORY OF CALL

THE NUMBER OF CENTRALLY-DISPATCHED POLICE EVENTS IS 10058

INTERARRIVAL MEAN IS 89 SECS

THE NUMBER OF MCSO ZONE B EVENTS IS 961

INTERARRIVAL MEAN IS 929 SECS

THE NUMBER OF AGENCY-TRANSFERRED POLICE EVENTS IS 1378

INTERARRIVAL MEAN IS 648 SECS

THE NUMBER OF FIRE EVENTS IS 1153

INTERARRIVAL MEAN IS 774 SECS

THE NUMBER OF EMS EVENTS IS 1122

INTERARRIVAL MEAN IS 796 SECS

SHERIFF'S EVENT GENERATION TIMES

DISTRICT : B01	PRIORITY : 1	ONSITE: FALSE	THE INTERARRIVAL MEAN IS 8753 SECONDS.	MONTHLY EVENTS =	102
DISTRICT : B01	PRIORITY : 1	ONSITE: TRUE	THE INTERARRIVAL MEAN IS 46989 SECONDS.	MONTHLY EVENTS =	19
DISTRICT : B01	PRIORITY : 2	ONSITE: FALSE	THE INTERARRIVAL MEAN IS 4398 SECONDS.	MONTHLY EVENTS	203
DISTRICT : B01	PRIORITY : 2	ONSITE: TRUE	THE INTERARRIVAL MEAN IS 19840 SECONDS.	MONTHLY EVENTS	45
DISTRICT : B02	PRIORITY : 1	ONSITE: FALSE	THE INTERARRIVAL MEAN IS 7763 SECONDS.	MONTHLY EVENTS =	115
DISTRICT : B02	PRIORITY : 1	ONSITE: TRUE	THE INTERARRIVAL MEAN IS 35712 SECONDS.	MONTHLY EVENTS =	25
DISTRICT : B02	PRIORITY : 2	ONSITE: FALSE	THE INTERARRIVAL MEAN IS 4442 SECONDS.	MONTHLY EVENTS =	201
DISTRICT : B02	PRIORITY : 2	ONSITE: TRUE	THE INTERARRIVAL MEAN IS 17856 SECONDS.	MONTHLY EVENTS =	50
DISTRICT : B03	PRIORITY : 1	ONSITE: FALSE	THE INTERARRIVAL MEAN IS 9704 SECONDS.	MONTHLY EVENTS	92
DISTRICT : B03	PRIORITY : 1	ONSITE: TRUE	THE INTERARRIVAL MEAN IS 15943 SECONDS.	MONTHLY EVENTS	56
DISTRICT : B03	PRIORITY : 2	ONSITE: FALSE	THE INTERARRIVAL MEAN IS 6200 SECONDS.	MONTHLY EVENTS	144
DISTRICT : B03	PRIORITY : 2	ONSITE: TRUE	THE INTERARRIVAL MEAN IS 8116 SECONDS.	MONTHLY EVENTS =	110
DISTRICT : B04	PRIORITY : 1	ONSITE: FALSE	THE INTERARRIVAL MEAN IS 46989 SECONDS.	MONTHLY EVENTS =	19
DISTRICT : B04	PRIORITY : 1	ONSITE: TRUE	THE INTERARRIVAL MEAN IS 148800 SECONDS.	MONTHLY EVENTS =	6
DISTRICT : B04	PRIORITY : 2	ONSITE: FALSE	THE INTERARRIVAL MEAN IS 35712 SECONDS.	MONTHLY EVENTS	25
DISTRICT : B04	PRIORITY : 2	ONSITE: TRUE	THE INTERARRIVAL MEAN IS 44640 SECONDS.	MONTHLY EVENTS	20
DISTRICT : B05	PRIORITY : 1	ONSITE: FALSE	THE INTERARRIVAL MEAN IS 40582 SECONDS.	MONTHLY EVENTS	22
DISTRICT : B05	PRIORITY : 1	ONSITE: TRUE	THE INTERARRIVAL MEAN IS 127543 SECONDS.	MONTHLY EVENTS =	7
DISTRICT : B05	PRIORITY : 2	ONSITE: FALSE	THE INTERARRIVAL MEAN IS 18600 SECONDS.	MONTHLY EVENTS =	48
DISTRICT : B05	PRIORITY : 2	ONSITE: TRUE	THE INTERARRIVAL MEAN IS 99200 SECONDS.	MONTHLY EVENTS	9
DISTRICT : B06	PRIORITY : 1	ONSITE: FALSE	THE INTERARRIVAL MEAN IS 297600 SECONDS.	MONTHLY EVENTS	3
DISTRICT : B06	PRIORITY : 1	ONSITE: TRUE	THE INTERARRIVAL MEAN IS 446400 SECONDS.	MONTHLY EVENTS	2
DISTRICT : B06	PRIORITY : 2	ONSITE: FALSE	THE INTERARRIVAL MEAN IS 223200 SECONDS.	MONTHLY EVENTS =	4
DISTRICT : B06	PRIORITY : 2	ONSITE: TRUE	THE INTERARRIVAL MEAN IS 223200 SECONDS.	MONTHLY EVENTS =	4
DISTRICT : UNK	PRIORITY : 1	ONSITE: FALSE	THE INTERARRIVAL MEAN IS 111600 SECONDS.	MONTHLY EVENTS =	8
DISTRICT : UNK	PRIORITY : 1	ONSITE: TRUE	THE INTERARRIVAL MEAN IS 892800 SECONDS.	MONTHLY EVENTS =	1
DISTRICT : UNK	PRIORITY : 2	ONSITE: FALSE	THE INTERARRIVAL MEAN IS 127543 SECONDS.	MONTHLY EVENTS =	7
DISTRICT : UNK	PRIORITY : 2	ONSITE: TRUE	THE INTERARRIVAL MEAN IS 111600 SECONDS.	MONTHLY EVENTS	8

UNITS PER EVENT

SOURCE OF CALL	CALL PRIORITY	NUMBER OF CARS	NUMBER OF CASES	PER CENT	CUM TOTAL	CUM %
CIT	1	1	90	0.247	90	0.247
CIT	1	2	133	0.365	223	0.613
CIT	1	3	90	0.247	313	0.860
CIT	1	4	31	0.085	344	0.945
CIT	1	5	13	0.036	357	0.981
CIT	1	6	7	0.019	364	1.000
CIT	2	1	429	0.661	429	0.661
CIT	2	2	158	0.243	587	0.904
CIT	2	3	49	0.076	636	0.980
CIT	2	4	9	0.014	645	0.994
CIT	2	5	1	0.002	646	0.995
CIT	2	6	3	0.005	649	1.000
SOURCE OF CALL	CALL PRIORITY	NUMBER OF CARS	NUMBER OF CASES	PER CENT	CUM TOTAL	CUM %
OFF	1	1	91	0.746	91	0.746
OFF	1	2	19	0.156	110	0.902
OFF	1	3	8	0.066	118	0.967
OFF	1	4	2	0.016	120	0.984
OFF	1	5	0	0.000	120	0.984
OFF	1	6	2	0.016	122	1.000
OFF	2	1	218	0.848	218	0.848
OFF	2	2	33	0.128	251	0.977
OFF	2	3	4	0.016	255	0.992
OFF	2	4	1	0.004	256	0.996
OFF	2	5	1	0.004	257	1.000
OFF	2	6	0	0.000	257	1.000

TELECOMMUNICATOR SERVICE TIME
TIME PERIOD : MAR 01 - MAR 31, 1987

POLICE CENTRAL DISPATCH PD

AGENCY TYPE	DURATION OF CALL	NUMBER OF CASES	PER CENT	CUM TOTAL	CUM %

GPSS FUNCTION : 0.037, 30/0.444, 60/0.773, 120/0.889, 180/0.930, 240/0.953, 300/0.953, 360/1.000,1499/					

PD	30	336	0.037	336	0.037
PD	60	3742	0.407	4078	0.444
PD	120	3027	0.330	7105	0.773
PD	180	1065	0.116	8170	0.889
PD	240	371	0.040	8541	0.930
PD	300	142	0.015	8683	0.945
PD	360	70	0.008	8753	0.953
PD	1499	433	0.047	9186	1.000

POLICE AGENCY TRANSFER = ND

AGENCY TYPE	DURATION OF CALL	NUMBER OF CASES	PER CENT	CUM TOTAL	CUM %

GPSS FUNCTION : 0.028, 30/0.401, 60/0.710, 120/0.858, 180/0.909, 240/0.933, 300/0.950, 360/1.000,1480/					

ND	30	23	0.028	23	0.028
ND	60	304	0.373	327	0.401
ND	120	252	0.309	579	0.710
ND	180	120	0.147	699	0.858
ND	240	42	0.052	741	0.909
ND	300	19	0.023	760	0.933
ND	360	14	0.017	774	0.950
ND	1480	41	0.050	815	1.000

FIRE DISPATCH = FD

AGENCY TYPE	DURATION OF CALL	NUMBER OF CASES	PER CENT	CUM TOTAL	CUM %

GPSS FUNCTION : 0.090, 30/0.658, 60/0.891, 120/0.942, 180/0.966, 240/0.972, 300/0.977, 360/1.000,1388/					

FD	30	91	0.090	91	0.090
FD	60	574	0.568	665	0.658
FD	120	235	0.233	900	0.891
FD	180	51	0.050	951	0.942
FD	240	25	0.025	976	0.966
FD	300	6	0.006	982	0.972
FD	360	5	0.005	987	0.977
FD	1388	23	0.023	1010	1.000

EMERGENCY MEDICAL SERVICES DISPATCH ED

AGENCY TYPE	DURATION OF CALL	NUMBER OF CASES	PER CENT	CUM TOTAL	CUM %

GPSS FUNCTION : 0.068, 30/0.604, 60/0.852, 120/0.922, 180/0.951, 240/0.963, 300/0.974, 360/1.000,1064/					

ED	30	67	0.068	67	0.068
ED	60	527	0.536	594	0.604
ED	120	244	0.248	838	0.852
ED	180	68	0.069	906	0.922
ED	240	29	0.030	935	0.951
ED	300	12	0.012	947	0.963
ED	360	10	0.010	957	0.974
ED	1064	26	0.026	983	1.000

PRE-DISPATCH SERVICE TIME
OF PRIMARY UNITS
TIME PERIOD : MAR 01 MAR 31, 1987

UNIT ORDER	AVAIL -%-	DURATION OF CALL	NUMBER OF CASES	PER CENT	CUM TOTAL	CUM %
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GPSS FUNCTION : 0.286, 0/0.766, 300/0.829, 600/0.879, 900/0.916,1200/0.931,1500/0.936,1800/1.000,2719/

1	50	0	99	0.286	99	0.286
1	50	300	166	0.480	265	0.766
1	50	600	22	0.064	287	0.829
1	50	900	17	0.049	304	0.879
1	50	1200	13	0.038	317	0.916
1	50	1500	5	0.014	322	0.931
1	50	1800	2	0.006	324	0.936
1	50	2719	22	0.064	346	1.000

GPSS FUNCTION : 0.336, 0/0.807, 300/0.884, 600/0.916, 900/0.940,1200/0.955,1500/0.966,1800/1.000,2527/

1	67	0	157	0.336	157	0.336
1	67	300	220	0.471	377	0.807
1	67	600	36	0.077	413	0.884
1	67	900	15	0.032	428	0.916
1	67	1200	11	0.024	439	0.940
1	67	1500	7	0.015	446	0.955
1	67	1800	5	0.011	451	0.966
1	67	2527	16	0.034	467	1.000

GPSS FUNCTION : 0.384, 0/0.848, 300/0.908, 600/0.954, 900/0.973,1200/0.981,1500/0.988,1800/1.000,2304/

1	89	0	159	0.384	159	0.384
1	89	300	192	0.464	351	0.848
1	89	600	25	0.060	376	0.908
1	89	900	19	0.046	395	0.954
1	89	1200	8	0.019	403	0.973
1	89	1500	3	0.007	406	0.981
1	89	1800	3	0.007	409	0.988
1	89	2304	5	0.012	414	1.000

GPSS FUNCTION : 0.441, 0/0.919, 300/0.964, 600/0.991, 900/1.000,1200/

1	100	0	49	0.441	49	0.441
1	100	300	53	0.477	102	0.919
1	100	600	5	0.045	107	0.964
1	100	900	3	0.027	110	0.991
1	100	1200	1	0.009	111	1.000
1	100	1500	0	0.000	111	1.000
1	100	1800	0	0.000	111	1.000
1	100	0	0	0.000	111	1.000

PRE-DISPATCH SERVICE TIME
OF ASSISTING UNITS
TIME PERIOD : MAR 01 MAR 31, 1987

UNIT ORDER	AVAIL -#-	DURATION OF CALL	NUMBER OF CASES	PER CENT	CUM TOTAL	CUM %

GPSS FUNCTION : 0.020, 0/0.558, 300/0.714, 600/0.779, 900/0.813,1200/0.847,1500/0.881,1800/1.000,3247/						

2	50	0	6	0.020	6	0.020
2	50	300	158	0.537	164	0.558
2	50	600	46	0.156	210	0.714
2	50	900	19	0.065	229	0.779
2	50	1200	10	0.034	239	0.813
2	50	1500	10	0.034	249	0.847
2	50	1800	10	0.034	259	0.881
2	50	3247	35	0.119	294	1.000

GPSS FUNCTION : 0.056, 0/0.599, 300/0.717, 600/0.788, 900/0.848,1200/0.874,1500/0.900,1800/1.000,3020/						

2	67	0	15	0.056	15	0.056
2	67	300	146	0.543	161	0.599
2	67	600	32	0.119	193	0.717
2	67	900	19	0.071	212	0.788
2	67	1200	16	0.059	228	0.848
2	67	1500	7	0.026	235	0.874
2	67	1800	7	0.026	242	0.900
2	67	3020	27	0.100	269	1.000

GPSS FUNCTION : 0.045, 0/0.689, 300/0.797, 600/0.870, 900/0.904,1200/0.921,1500/0.938,1800/1.000,2705/						

2	89	0	8	0.045	8	0.045
2	89	300	114	0.644	122	0.689
2	89	600	19	0.107	141	0.797
2	89	900	13	0.073	154	0.870
2	89	1200	6	0.034	160	0.904
2	89	1500	3	0.017	163	0.921
2	89	1800	3	0.017	166	0.938
2	89	2705	11	0.062	177	1.000

GPSS FUNCTION : 0.211, 0/0.737, 300/0.842, 600/0.895, 900/0.947,1500/1.000,9060/						

2	100	0	4	0.211	4	0.211
2	100	300	10	0.526	14	0.737
2	100	600	2	0.105	16	0.842
2	100	900	1	0.053	17	0.895
2	100	1200	0	0.000	17	0.895
2	100	1500	1	0.053	18	0.947
2	100	1800	0	0.000	18	0.947
2	100	9060	1	0.053	19	1.000

APPENDIX B
SAMPLE MODEL OUTPUT

SUMMARY STATISTICS

COPS
Countywide Police Simulation

MONROE COUNTY SHERIFF'S DEPARTMENT
ZONE B - DISTRICTS 1-7

RUN # 1

COMMENTS: COPS

UNIT DISTRICT	UNIT ID
1	618
1	619
2	616
2	617
3	627
3	628
3	629
4	623
5	621
7	SUP
7	FLT

THERE ARE 8 TELECOMMUNICATORS ON DUTY.

DISTRICT DISPATCH PLAN

DISTRICT	FIRST RESPONSE	SECOND RESPONSE	THIRD RESPONSE	FOURTH RESPONSE	FIFTH RESPONSE	SIXTH RESPONSE	SEVENTH RESPONSE

B1:	B1	B2	B6	B4	B5	B7	B0
B2:	B2	B1	B6	B3	B4	B7	B0
B3:	B3	B2	B4	B6	B7	B0	B0
B4:	B4	B2	B1	B6	B5	B7	B0
B5:	B5	B4	B1	B7	B0	B0	B0
B6:	B6	B1	B2	B4	B7	B0	B0

THE FOLLOWING MODULES WERE ENABLED FOR RUN # 1

ENABLED MODULE: DISPATCH PLAN & UNIT SELECTION
 ENABLED MODULES: PRE-DISPATCH, TRAVEL, AND SERVICE TIMES
 EVENT GENERATION MODE: PROBABILISTIC

PATROL ACTIVITY STATISTICS

UNIT DIST	UNIT ID	# OF CALLS	BUSY % SHIFT	RESPONDING % IN	% OUT	AT SCENE % IN	% OUT	AVERAGE TIME PER CALL (MIN)
1	618	10	65.92	14.07	5.08	34.74	12.03	32
1	619	9	64.30	9.08	6.25	27.14	21.84	34
2	616	8	54.75	9.69	3.23	32.25	9.58	33
2	617	8	53.27	8.07	5.39	23.53	16.28	32
3	627	5	30.94	6.46	1.61	17.70	5.17	30
3	628	5	30.30	6.46	1.61	17.15	5.08	29
3	629	5	31.03	6.46	1.61	17.47	5.49	30
4	623	4	27.72	1.61	4.84	5.05	16.21	33
5	621	4	27.35	4.84	1.61	16.73	4.17	33
7	SUP	5	29.35	0.00	7.99	0.00	21.36	28
7	FLT	1	6.78	0.00	1.61	0.00	5.17	33

PRE-DISPATCH TIME

-DISTRICT-	-MAX- NUM	-AVG- NUM	-TOTAL- CALLS	-WAITERS-	-AVG- TIME ALL (MIN)	-AVG- TIME WAITERS (MIN)
1	1	0	13	3	1.15	4.99
2	2	0	13	10	5.38	6.99
3	1	0	8	3	1.87	4.99
4	1	0	2	1	2.49	4.98
5	1	0	2	2	7.49	7.49
6	0	0	0	0	0.00	0.00
ZONE	2	0	38	19	3.15	6.31

RESPONSE TIMES BY DISTRICT

-DISTRICT-	-CALLS-	-MEAN-	-STD. DEV-
1	13	8.31	1.49
2	13	7.00	0.71
3	8	7.00	0.00
4	2	7.00	0.00
5	2	7.00	0.00
6	0	0.00	0.00
ZONE	38	7.45	1.13

SERVICE TIMES BY DISTRICT

-DISTRICT-	-CALLS-	-MEAN-	-STD. DEV-
1	13	25.77	0.83
2	10	26.60	0.97
3	7	18.86	2.27
4	2	24.00	0.00
5	2	29.00	1.41
6	0	0.00	0.00
ZONE	34	24.68	3.38

PREVENTIVE PATROL

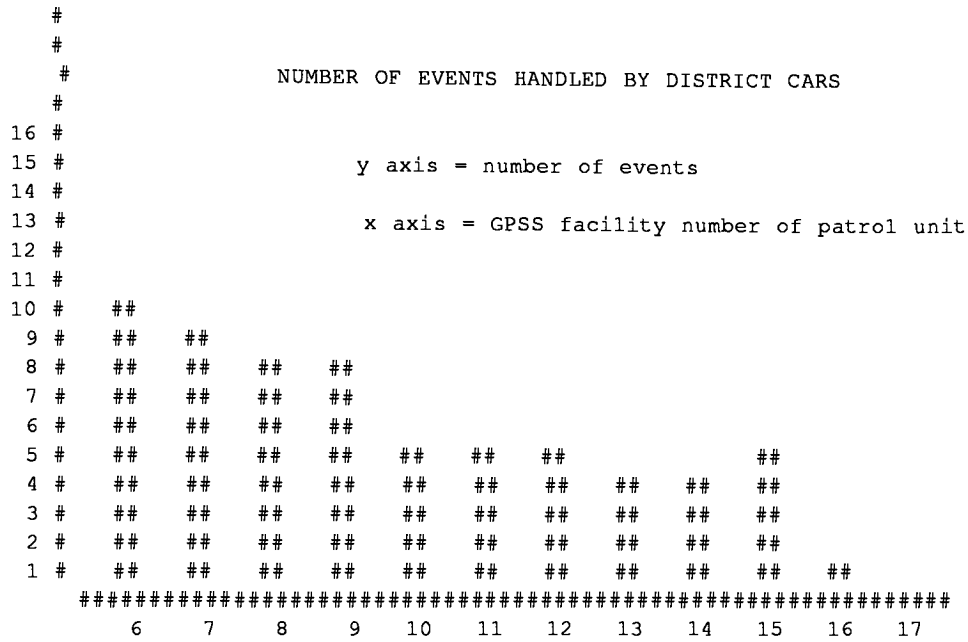
AT ANY GIVEN MOMENT DURING THE 2 PM TO 10 PM SHIFT,
AN AVERAGE OF 7 UNITS ENGAGED IN PREVENTIVE PATROL.

THE DETAILED BREAKDOWN IS AS FOLLOWS:

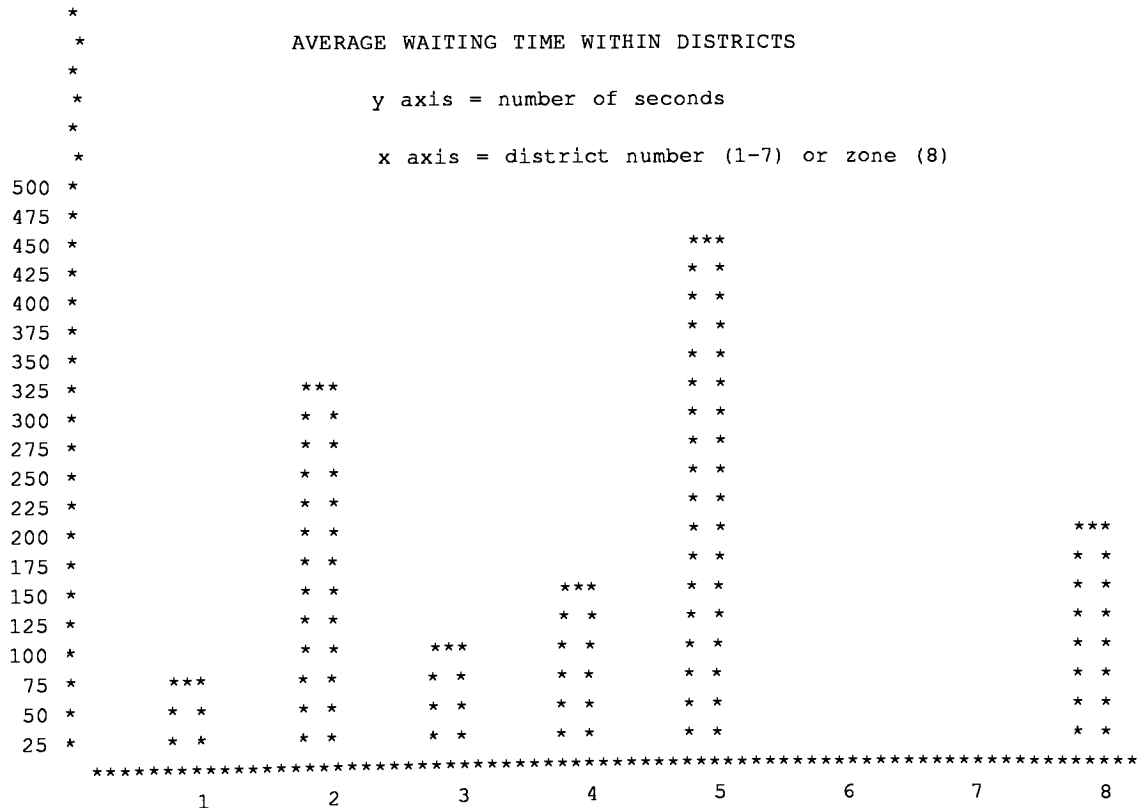
NUMBER OF CARS V	FREQUENCY V	MORE THAN COL 1 CARS V
UPPER LIMIT	PERCENT OF TOTAL	CUMULATIVE REMAINDER
0	0.21	99.79
1	3.13	96.66
2	2.30	94.36
3	1.04	93.32
4	7.72	85.59
5	12.32	73.28
6	13.78	59.50
7	20.04	39.46
8	18.79	20.67
9	12.11	8.56
10	2.09	6.47
11	6.47	0.00

 * GRAPHS *

 GRAPH 1 *



 GRAPH 2 *



APPENDIX C
BENCHMARK EVALUATION TABLES

CAD BENCHMARK EVALUATION TABLES

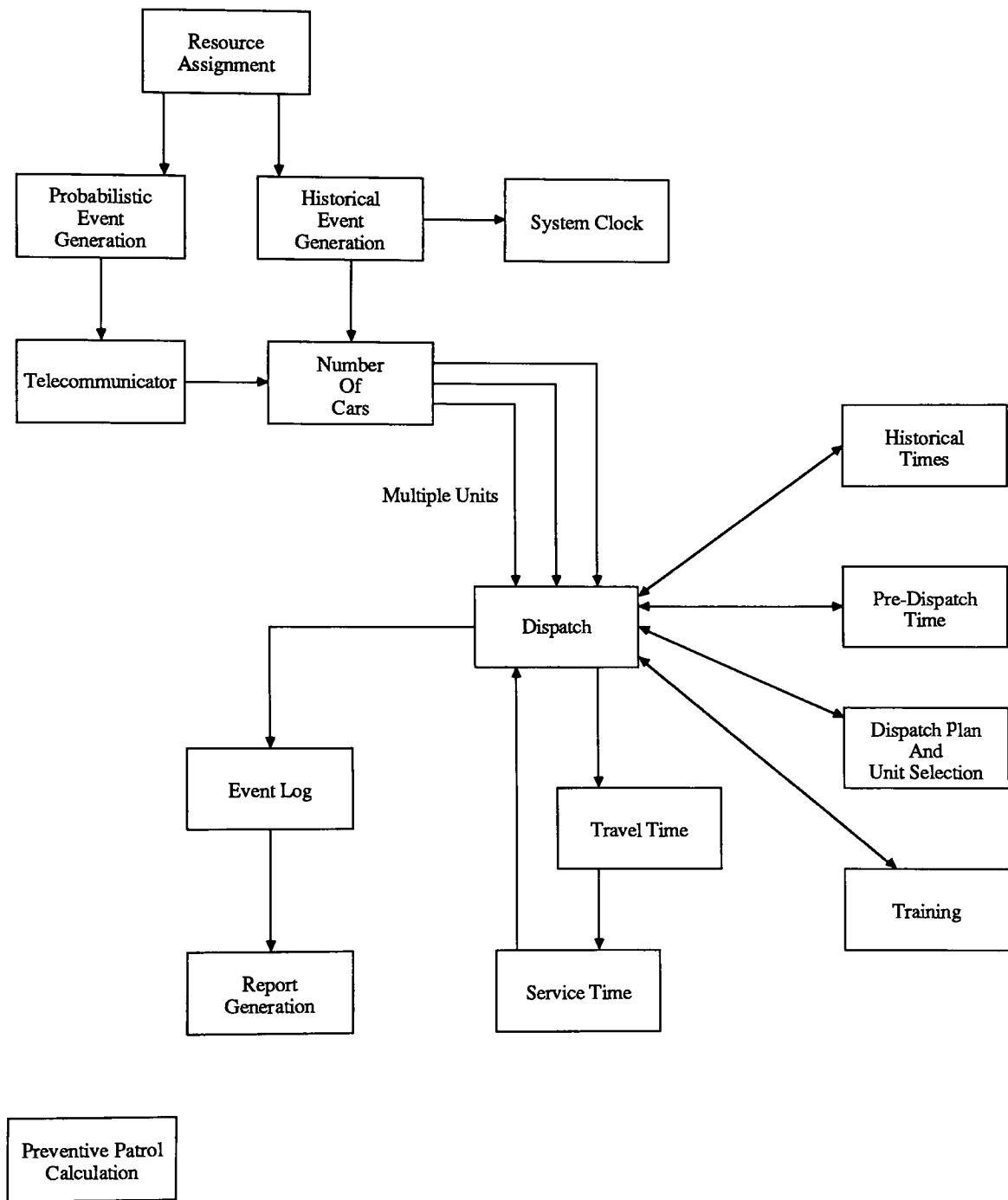
MCSO ACTIVITY REPORT FOR JUNE 1, 1987

UNIT DISTRICT	UNIT ID	NUMBER OF CALLS	BUSY AS % OF SHIFT	RESPONDING		AT SCENE		AVERAGE TIME PER CALL (MIN)
				% IN	% OUT	% IN	% OUT	
B00	610	1	1.04%	0.00%	0.00%	0.00%	1.04%	5.00
B01	618	10	52.71%	10.83%	1.46%	18.13%	22.29%	25.30
B01	619	3	44.38%	0.00%	0.00%	0.21%	44.17%	71.00
B02	616	8	27.50%	2.71%	8.13%	5.00%	11.67%	16.50
B02	617	8	51.88%	3.33%	4.17%	42.08%	2.29%	31.12
B03	627	11	35.83%	11.46%	0.21%	24.17%	0.00%	15.64
B03	628	3	9.79%	0.21%	0.83%	8.75%	0.00%	15.67
B03	629	7	39.38%	7.71%	1.67%	29.37%	0.62%	27.00
B04	623	4	16.46%	0.00%	0.21%	16.25%	0.00%	19.75
B05	621	2	6.67%	0.00%	1.46%	3.75%	1.46%	16.00
XXX	937	2	8.96%	0.00%	2.29%	0.00%	6.67%	21.50

WAITING LINE STATISTICS

MCSO ZONE B DISTRICT	MAX NUMBER WAITING	NUMBER REQUESTING SERVICE	NUMBER WHO WAITED	AVG WAIT TIME (MINS) OF ALL	AVG WAIT TIME (MINS) OF WAITERS
ZONE B	3	38	26	4.63	6.77

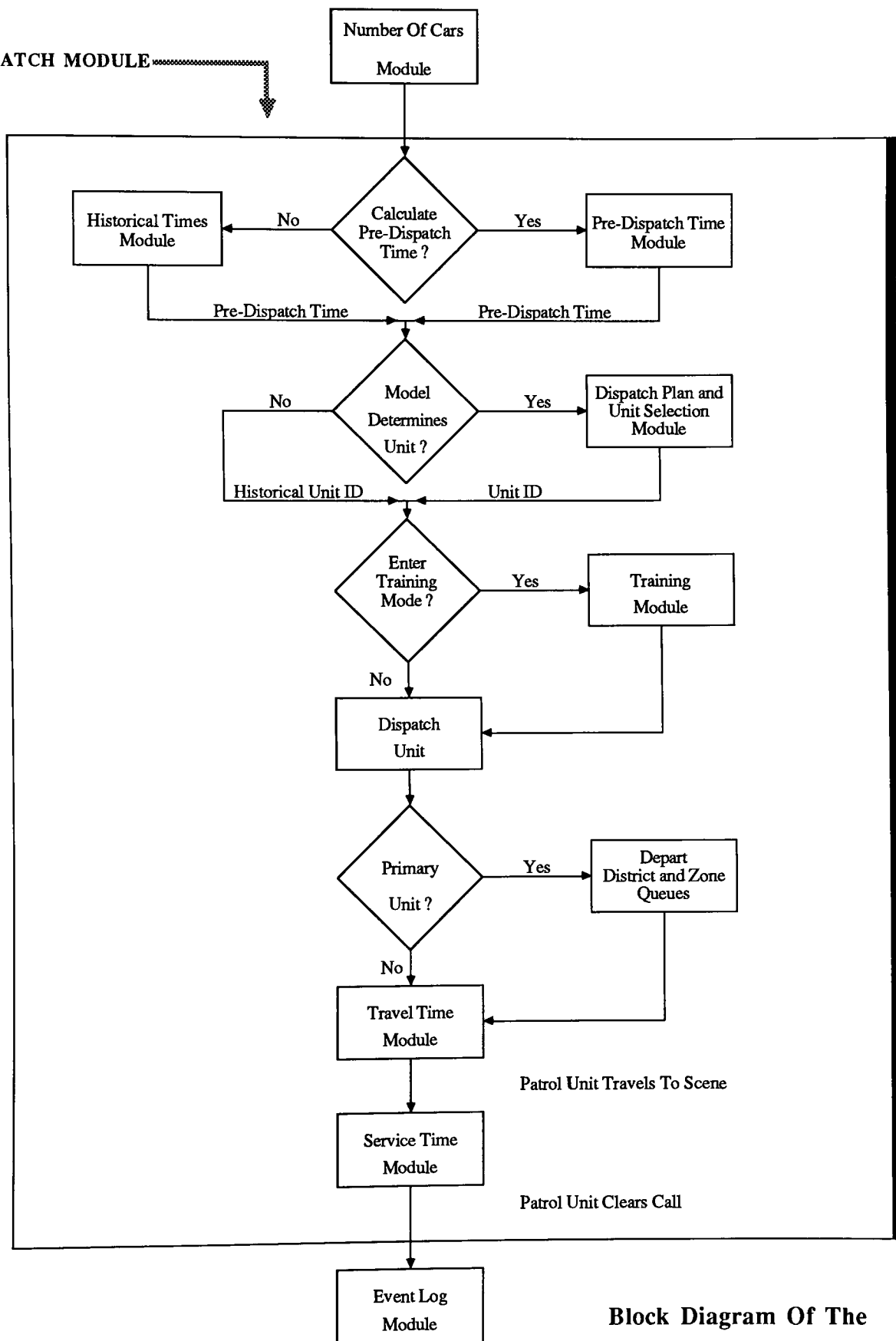
APPENDIX D
BLOCK DIAGRAMS



Countywide Police Simulation System

Module Overview

DISPATCH MODULE



Block Diagram Of The
Dispatch Module

