EVALUATION OF AN AVM SYSTEM IMPLEMENTED CITY-WIDE IN ST. LOUIS

A SUMMARY REPORT

by

Gilbert C. Larson

Project Advisors:

Richard C. Larson, Ph.D.
Kent W. Colton, Ph.D.

Work on this evaluation project is being supported by Grant Nos. 75NI-99-0014 and 76NI-99-0095 from the National Institute of Law Enforcement and Criminal Justice, Law Enforcement Assistance Administration, U.S. Department of Justice. Points of view or opinions stated in this document are those of the authors and do not necessarily represent the official position or policies of the U.S. Department of Justice.

June, 1978

Public Systems Evaluation, Inc.
929 Massachusetts Avenue
Cambridge, Massachusetts 02139

EVALUATION OF AN AVM SYSTEM

IMPLEMENTED CITY-WIDE IN ST. LOUIS

A SUMMARY REPORT

An Automatic Vehicle-Monitoring (AVM) system provides real-time location and status information for each vehicle in the system. Typically, the system would include a display showing a map of the city (presented in several scales) with cars, including their identification number, properly positioned on the map. This report is a Phase II evaluation of such a system implemented city-wide by the St. Louis Metropolitan Police Department.

The principal goal was reduction in response time, which, it was believed, would increase the rate of criminal apprehension and possibly deter crime because of time saved by always dispatching the car closest to an incident site. Other objectives included improved officer safety, more effective command and control, less voice band congestion because of the digital communications included in the AVM system and better supervision of the force.

The evaluation results were unfavorable for response time reduction, favorable for improved operations due to digital communication and mixed in the realization of other objectives. Poor system performance had some influence on the evaluation results. During the process of evaluation, it became clear that full system potential could not be assessed without some change in police procedures and operating methods. Such potential (which is yet to be verified) relates to the use of directed dispatch rather than the all points broadcast (APB) for extraordinary events such as pursuits, burglaries, and disturbances; the dynamic reallocation of the force to maintain a patrol presence or to reduce queuing levels in areas where excessive calls for service have depleted the force availability; and better supervision of the force made possible by the new information that the AVM system supplies. Also AVM serves as a hidden supervisor producing better officer behavior. An outgrowth of these potentials can be improved effectiveness of the force, greater productivity, and a cost-effective system.

The evaluation methodology involves three separate analyses: technological, operational, and attitudinal. A cost-effectiveness analysis is included.

Author: Gilbert C. Larson

Address: Public Systems Evaluation, Inc.
929 Massachusetts Avenue
Cambridge, MA 02139
(617) 547-7620

Panel: Evaluating Police Practice

EVALUATION OF AN AVM SYSTEM
IMPLEMENTED CITY-WIDE IN ST. LOUIS

A SUMMARY REPORT

Automatic Vehicle Monitoring (AVM) systems use advanced technology to track the position of vehicles and to monitor their general status. Sometimes called automatic vehicle location (AVL) systems, they use one of several currently available technologies to estimate a vehicle's position. These technologies usually build around one of the following concepts: radio ranging ("trilateration"), proximity sensing (e.g., a vehicle passing a sensor at an intersection), or dead-reckoning (e.g., in-vehicle position updating, such as in submarines). Some systems--called hybrid systems--incorporate two or more of these concepts along with other concepts such as computer correction of tracking errors.

The "monitoring" aspect of an AVM system usually includes status information in addition to location. In police applications the status may describe whether the vehicle is responding to a police call-for-service, at the scene (servicing a call), or involved in routine preventive patrol, in hot criminal pursuit, or in need of emergency assistance.

The potential for AVM systems in law enforcement agencies was originally suggested by studies undertaken by the President's Crime Commission (1966) wherein it was suggested that AVM--by automatically dispatching the closest patrol car--could cause a significant reduction in travel time (and a corresponding reduction in overall response time). Some conjectured that AVM could be a deterrent to crime because more criminals would be apprehended. Even earlier though the need and application of

AVM was evident in public transportation, where as early as 1935 a crude form of vehicle monitoring was implemented by the Chicago Transit Authority leading eventually to a much more sophisticated system in the early 1970's (implemented by Motorola) which provided real-time data for an automatic schedule adherence system, an emergency alarm system, and other features permitting better supervision and safety.

A. AVM in Law Enforcement Agencies

The President's Crime Commission reports stirred considerable interest within the industry to develop systems that could meet the basic requirement for automatic selection of the police cars closest to an incident site with the expectation that such a system would reduce response time to the extent that more criminals would be apprehended. If this concept proved successful the market potential appeared attractive because a system that reduces crime--especially if paid for by federal funds--is difficult to refuse.

Over ten industrial companies invested their monies and talents in the early 1970's in an effort to develop an appropriate system. Most designs were variations of the three basic system types mentioned in the opening paragraph. The Law Enforcement Assistance Administration (LEAA), too, was following these developments with considerable anticipation. It was during this period of high expectation that the LEAA awarded the Boeing Company a contract to implement their AVM system in one police district in St. Louis,[1] and awarded Public Systems Evaluation, Inc. (PSE)

---

[1] The AVM system was a computer-assisted dead-reckoning type. Implementation commenced in mid-1974.

a grant to evaluate the results. This was the first attempt to install a sophisticated AVM system in a major metropolitan area. After completion of the Phase I program--which yielded some successes and some disappointments--[2] a Phase II program was initiated to implement the entire city. The evaluation results of the Phase II program are presented in this paper.[3] The Phase II evaluation was completed in January 1978.

Other noteworthy police-related developments in this interesting new technological field include the implementation of a proximity signpost system in Huntington Beach, California, by the Hoffman Company during 1975-76, and the implementation of a pulse-trilateration system by the Hazeltine Corporation in one of the large Dallas police districts during 1977-78. The Department of Transportation (DOT) has also shown keen interest in AVM, primarily in its ability to improve the safety and schedule adherence of their transport systems. DOT conducted a competitive test in the City of Philadelphia during 1977 involving four suppliers: Fairchild Industries, Hazeltine, Hoffman, and Teledyne. The Hoffman Company won the competitive test and was awarded a contract to implement their proximity signpost system in an area of Los Angeles. It is to serve both fixed and random route bus systems as well as other public agencies--such as the Los Angeles Police Department--and perhaps private industry--such as delivery truck systems and/or taxi cabs.

---

[2] R.C. Larson, K.W. Colton, and G.C. Larson, "Evaluation of a Police-Implemented AVM System - Phase I, A Summary Report" (Public Systems Evaluation, Inc., Cambridge, 1976). Available from the U.S. Government Printing Office, Washington, D.C. 20402, stock no. 027-000-00525-0.

[3] For a more complete report, see "Evaluation of a Police AVM System, A Phase II City-wide Implementation by G.C. Larson and J.W. Simon, available from NILECJ.

B. The FLAIR AVM Systems

1. The computer-assisted, dead-reckoning system known as FLAIR [4] is a product of the Boeing Company, Wichita Division. Car location is determined by data supplied from each car involving distance traveled (from an odometer) and direction of travel (from a magnetic heading sensor). This incremental data is transmitted to the base station each update period (about 1.2 second intervals) where the computer applies such updates to the previous data (and the car's original initialized position) to present continuous tracking of the vehicle's location on a color TV-type map display. A characteristic of dead-reckoning systems is that the vehicle being tracked will eventually become "lost" due to accumulation of error. To delay this process the FLAIR system uses the computer to keep the car located on streets (rather than wondering from side to side) and corrects distance error when a corner is turned (through a map-matching process). The estimated vehicle location still can become lost, however, and when this happens the computer notifies the dispatcher to stop the real vehicle and verify its location. If the location is incorrect, the dispatcher will correctly locate it (this process is called reinitialization).

The performance of the FLAIR system was below expectations throughout the Phase II evaluation period. Only 50% of the vehicles showed no measurable error compared to 80% during Phase I, and 95% of the vehicles were within 3000 feet of the correct location in Phase II compared to 700 feet in Phase I. Also the frequency of lost cars was too high, causing additional workload for both the dispatcher and the officer because of excessive reinitializations that were required. Poor performance had an adverse affect on officer and dispatcher attitudes and on some of the

[4] FLAIR is a trademark of the Boeing Company, and stands for Fleet Location And Information Reporting. Patents have been applied for in the United States and in foreign countries.

evaluation results. More recently, and several months after the evaluation program was completed, the performance has been improved by instituting a preventive maintenance program, increasing the number of self-initialization points[5] and other fixes. According to the contractor, the accuracy is now equal to that measured during Phase I, when 80% of the vehicles showed no measurable error.

C. Evaluation Methodology

A new technology such as AVM is generally conceived for the purpose of improving the operations of a system and, to enhance the possibility of success, the new technology should be cost-effective. This then suggests that an evaluation program should include components that will (1) measure the technical adequacy and performance capability, and (2) measure the improvement that impacts the operating system, including its cost-effectiveness. Other reactions from urban planners and sociologists suggest that attitude towards and acceptance by police personnel to AVM systems will be among the most critical factors in implementing these systems in police departments today--in fact, they may be more critical than any particular technological problem. The evaluation methodology then builds on three prongs: technology, operations, and attitudes.

D. AVM System Objectives

The St. Louis Metropolitan Police Department (SLMPD) established four major objectives for the system and a fifth was added during the Phase II evaluation period.

---

[5] A self-initialization point is a marked location where the officer stops his vehicle and then keys in the appropriate digital code. This operation correctly reinitializes the car without dispatcher assistance.

1. Reduce response time
2. Improve officer safety
3. Reduce voice-band congestion
4. Enhance command and control capabilities
5. Improve supervision of the force

These five objectives, together with system costs, provide a framework for considering the overall cost-effectiveness of the system.

E. Evaluation Results

1. Response time. On first analysis it seems obvious that the ability to select the closest car for dispatching should result in improved response time by reducing response time distances. But even though such a closest car dispatching plan was adhered to very closely during Phase II, *there was no significant improvement in travel times*. On the whole, response times seemed somewhat longer after FLAIR became operational, but there were many reasons besides the closest car dispatching process (e.g., less experienced dispatchers) which could have caused this pattern. In any case, response time reductions do not appear to be the popular benefit of AVM contrary to what many had expected.

Evaluation of response time performance is particularly important because response time is often a major design criterion for AVM manufacturers. For this reason, this aspect of AVM has received extra emphasis in this evaluation. In order to assure the validity of evaluation conclusions, several different measurements of the effect of AVM on response time are included in this analysis:

- Simulation model of AVM impact on response time
- Detailed analysis of travel time by priority of call
- Detailed analysis of dispatch times by priority of call
- Overall Phase II response time results
- Phase I special test results

Every approach to AVM response time evaluation indicates that only limited improvements can be expected. From the simulation model, it has been estimated that under ideal conditions, potential savings in travel time of 11% to 15% were attainable (about one-half minute); in practice maximum savings of 15-20 seconds were attained. There was no difference in response time savings between priority 1, 2, or 3 calls. Poor accuracy had some effect on the results, but in the opinion of the evaluators, not enough to change the above conclusion. When these are considered in the light of the results of the recently completed Kansas City Response Time Study,[6] it is apparent that response time will not be the area in which AVM has its greatest potential. The Kansas City study showed that the time taken to report an incident after its occurrence is comparable to or greater than travel time for most crime categories, thus diluting the influence of travel time savings on greater criminal apprehension and witness availability.

Closest car dispatching is of value principally during periods of intermediate workload. If most cars are available, the closest car is usually the sector car and no additional benefit is derived from using the closest car dispatching strategy. Similarly, if only a few cars are avail-

---

[6] Marvin L. Van Kirk, "Response Time Analysis - Executive Summary" (Kansas City, Missouri Police Department, 1977).

able, the closest one will usually be obvious to the dispatcher without the aid of AVM.

2. Increase officer safety. An emergency button is located on the push-button panel assembly in the patrol car that the officer can activate when he is in trouble. Evaluation of the emergency aspects were influenced by the poor accuracy of the AVM system, by equipment malfunction, and improper use by the officer. True emergencies were masked by too many false alarms, and about half were ineffective because of poor accuracy. In times of need the officers prefer to use voice radio, in combination with the emergency button activation. Officer safety still appears to be a potentially positive aspect of AVM from the patrol officers perspective. At this point, though, the police are somewhat skeptical, and the impressions of the past several years must be modified if attitudes are to be changed. In fact, during interviews it became apparent that what the officer really wants is an emergency button on the belt, that can be activated when the officer is out of the vehicle. Boeing had originally proposed such an accessory, but it was never produced due to budgetary constraints.

3. Decrease voice-band congestion by digital communication. When city-wide FLAIR was made operational, many officers, dispatchers, and police managers commented on the decrease in voice-band usage. Digital communication offers an additional means (by coded messages) of officer communications to the dispatchers, via the AVM radio channel. It provides instant communication to the dispatcher; it allows the dispatcher to respond by priority of message (rather than by sequence of arrival); and it appears to be well-liked,

particularly by the officers. Most dispatchers, though, perceive the responding to digital codes via voice radio as an increase in workload. In general, the greatest benefit of digital communication is that it offers an additional means of communication that increases information transfer and the potential for improved police effectiveness and efficiency.

4. Improve command and control capability. Because FLAIR provides real time location and status of all patrol cars on the display console, the dispatcher is provided with information (not heretofore available) that facilitates a higher level of command and control of the forces. With this tool, the dispatcher can now direct strategic deployment of the force for pursuits, sealing off an area, burglaries in process, etc., rather than the less efficient process of issuing an all-points-broadcast (APB). Proper evaluation of this capability involves the implementation of new police methods and procedures, which unfortunately were not accomplished during the evaluation period because of the attention required on more pressing items (correcting for poor accuracy, training of personnel, etc.). On a few occasions, individual dispatchers would conduct a pursuit and other in-process events, by directing specific deployment, with encouraging results. Full assessment of this capability must await policy directives that will focus on this new methodology.

5. Improve supervision of the force. AVM itself serves as a *hidden supervisor* in that patrol officers know they can be watched. which tends to influence officers toward better behavior. Even with

poor accuracy, this purpose is served, because at any time the dispatcher can call for a "FLAIR check" which directs the officer to stop his vehicle and state his location. If he responds over the voice radio with a location that is far from his beat area (and without cause), it would be normal for him to feel embarrassed and to reduce the frequency of such occurrences. Quantitative data on officer behavior is difficult to obtain, because data prior to AVM implementation are not available. However, FLAIR display viewings of numerous individual cars show performance behavior that generally appears to be good, and questionnaires from dispatchers and officers, and interviews with officers and police management indicate support for this belief. Although little hard evidence exists, the indications allow us to hypothesize that AVM can lead to improved patrol performance.

Another supervision tool is to gather data at a city-wide console by observing and recording vehicle activity in each district at periodic intervals. Such data can include the number of cars moving and not moving; the number of cars available for call, on call, or unavailable; the number of cars out of the district ; and the number of cars at the district station. From these data, performance trends can be plotted and poorer than average results can be the subject for roll call discussions.

There may be a strong temptation to use AVM as an inspection device for catching an officer in some improper act, which then could lead to disciplinary action. Such use is believed wrong and may be counterproductive by causing acts of subversion, poor morale and possible labor disputes. Application of AVM to improve supervision may yield positive results, and application for spying and disciplinary purposes should be avoided.

F. The Potential of AVM

The potential of AVM is dependent upon the recognition by the law eforcement agency of the services it can render, and adopting methods and procedures where necessary to take advantage of these services. The measure of achievement can perhaps be best expressed by relating productivity improvement to AVM system and operating cost.

1. Adapting operations to AVM. Proper utilization of AVM to affect the cost and other benefits that can accrue requires more than just implementing the system; the methods, procedures, and organization of the department should be carefully reviewed to accommodate the capabilities of the system. Examples follow.

a. Extraordinary events. Normally a dispatcher serves a district, or some prescribed area. In St. Louis, six dispatchers serve nine districts. Each dispatcher has an AVM display console to assist in the conduct of his/her duties. However, should some extraordinary event occur--such as a pursuit--the dispatcher would be unable to direct the pursuit beyond his/her own district. This gives rise to the need for a *city-wide console*, located in the dispatch area, that can take over such dispatch tasks.

b. Supervision. AVM can serve as a tool to improve supervision capability. The dispatcher at the city-wide console can establish a routine for recording the activity of all patrol cars by district at periodic intervals. Such information will develop trends of productive/non-productive activities which supervisors can use as a basis for improving performance.

The city-wide dispatchers can observe actions of individual cars, and when observations indicate probable non-productive actions, such as bunching or a patrol car located a considerable distance from his beat, the dispatcher can ask for his location (or other soft inquiry) that serves to signal the officers that the patrol force is being observed. The intent is to provide an awareness so that their behavior patterns improve. AVM should not be used for internal inspection and subsequent disciplinary actions.

2. Productivity improvement. During Phase II the assessment of productivity improvement relating to the five objectives was not attempted because of performance factors and other constraints. However, some information--mostly subjective--was acquired relative to the effect of AVM on improving officer performance.

- The final questionnaire had a question, "Remembering that FLAIR provides dispatchers with the location of all patrol vehicles, do you think that FLAIR has made a difference in the following areas?" The officer replies were:

  Re: Patrol cars leaving the district: 21.6% indicated a decrease, 11.1% an increase, the remainder unchanged.

- Although before-after information was not available, random observations made of numerous patrol cars (15 to 20) for an hour or more each at the city-wide console revealed behavioral practices that were generally good, showing essentially no evidence of abnormal practice (e.g., bunching, leaving the district, etc.)

- Interviews with police sergeants, lieutenants, and captains seemed to support the belief that attention to patrol duties has improved. Although most were hesitant on estimating the percentage of improvement, some were willing to estimate that the improvement could be 10% (or more).

3. FLAIR system and operating cost. Productivity improvement should be balanced against the cost involved in improving the productivity. Such costs include the capital investment of the system plus the added operating and maintenance cost. The following system estimates are based upon Phase II costs as provided by the contractor, but do not necessarily reflect the ultimate production cost.

Capital Investment

Mobile equipment for 200 cars	$ 842,000
Base equipment for FLAIR system	908,000
Estimated value of usable Phase I equipment	140,000
Special test equipment	24,000
Total investment	$1,924,000
Cost per car	9,620
Installation cost per car	40
Total cost per car	$ 9,660

Operating Cost (estimated)

One FLAIR coordinator (with fringe & overhead)	$ 17,500/year
Operating supplies	1,500
Total operating cost	$ 19,000/year

Maintenance Cost

Computer contract	$ 32,000/year
Eleven technicians (average $9,000 at one-half time)*	85,500
Spare parts (estimated)	23,000
Total maintenance cost	$ 140,500/year

*One-half time for FLAIR, one-half time for voice communication equipment

4. Return on investment. The total cost of a one-man police car is approximately $130,000 per year. This assumes five officers are assigned to each patrol car to cover three shifts, holidays, vacations, and sick time, and the proportionate share of vehicle and equipment cost. A two-man car is approximately twice the cost of a one-man car--$260,000 per year. Thus, percentage of productivity improvement needed to break even is calculated in the following.

	One-Man Car		Two-Man Car	
Amortization basis	10-year	5-year	10-year	5-year
FLAIR cost per car per year	$1,766	$2,732	$1,766	$2,732
Operating cost per car per year	$130,000	$130,000	$260,000	$260,000
% productivity improvement to break even	1.36%	2.1%	0.7%	1.05%

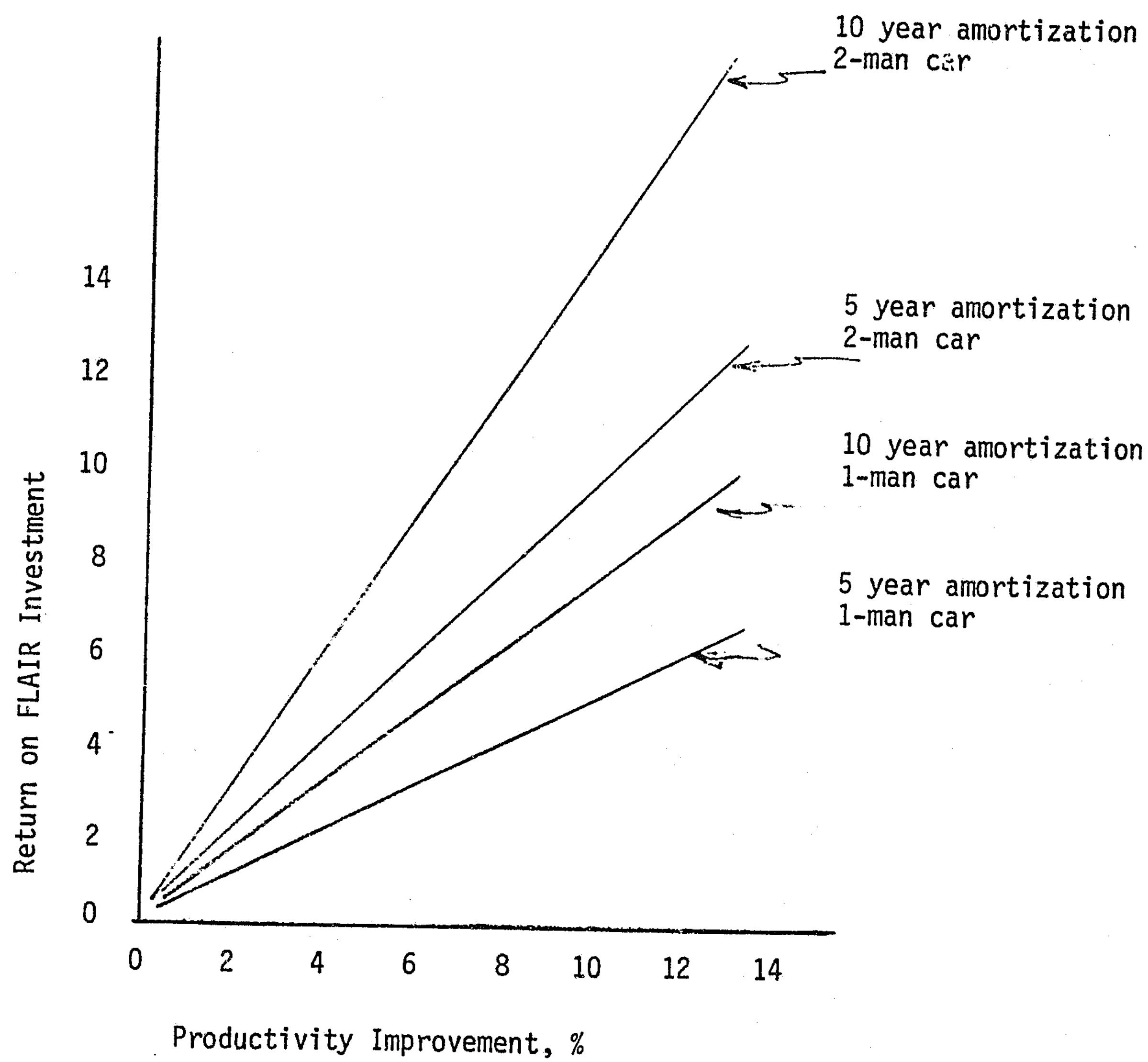
A one-man car amortized on a five-year basis requires only 2.1% improvement in productivity to pay for the FLAIR system; in contrast, a two-man car requires only 0.7% improvement when amortized on a ten-year basis. It would appear very unlikely that the productivity would not increase by these amounts. For higher levels of productivity improvement versus return on investment, see Exhibit 5-1. For "reasonable" levels of productivity improvement--such as five to ten percent, the return on investment appears very attractive, ranging from over 2:1 to 14:1. For a five percent improvement and a ratio of 3 one-man cars to 1 two-man car, the return would be 3:1 on a five year amortization, or 4.5:1 for a ten-year amortization.

Exhibit 5-1

Return on FLAIR Investment

vs.

Productivity Improvement



Still, the link between AVM and such returns has yet to be established. What remains is to demonstrate the effect on police operations of AVM when it is deployed in a manner to more fully use its capabilities and to develop measures that will determine a more definitive value of productivity improvement.

6. AVM as a research tool. Conceptual uses for AVM originally envisioned improvement in response time, officer safety, and voice band congestion when applied to a conventional dispatch system. After implementation, other and perhaps greater benefits became apparent. These require modification of police practices and methods to accommodate the new technology (e.g., use of directed dispatch rather than the APB method, and improved supervision of the forces). As the use of AVM continues, more innovative applications are likely to develop.

An example of an unanticipated use occurred during the preparation of the paper "Markov Models of Fixed-Post Sensor AVL Systems." During the development of the mathematical models, it became necessary to determine the probability of a patrol car turning at the next intersection. The literature seemed void of such data; and acquiring reliable results using conventional methods appeared time-consuming and expensive. Using AVM, however, the results were easily, quickly, and accurately obtained simply by observing the behavior of random patrol vehicles on the display screen. A histogram of the number of blocks travelled between turns shows a geometric distribution with the mean equaling 4.0 blocks between turns. For this application, AVM served as a *research tool*.

Additional research applications are apparent and other new ones undoubtedly will develop. Some of the apparent ones include:

- The total patrol car response to an APB (All Points Broadcast) message.
- The degree of conformity to established patroling routines.
- The spatial dependence between crime occurrences and patrol passings.

Some of the above applications would be greatly assisted by an AVM playback capability. Such a feature allows analysis of patrol operations after the occurrence at an efficient 10 times normal speed. Playback can provide legal evidence of the time and degree of response to any particular incident. A playback capability should be an important consideration for those planning an AVM system.

END