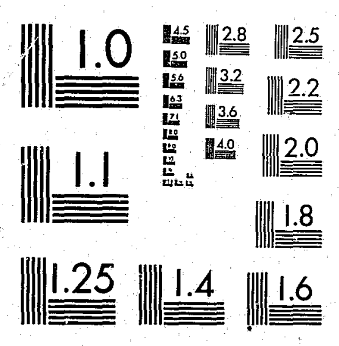

MICROCOPY RESOLUTION TEST CHART
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MINNESOTA

CRIME CONTROL PLANNING BOARD

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AN EVALUATION OF MINNESOTA'S AUTOMATED FINGERPRINT IDENTIFICATION SYSTEM (MAFIN)

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RESEARCH AND EVALUATION UNIT REPORT

An Evaluation Report

Produced by the

RESEARCH AND EVALUATION UNIT

of the

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444 Lafayette Road

St. Paul, Minnesota 55101

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by

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AN EVALUATION OF MINNESOTA'S AUTOMATED FINGERPRINT IDENTIFICATION SYSTEM (MAFIN)

EXECUTIVE SUMMARY

In December 1978 Minnesota put into operation an automated latent fingerprint identification system (MAFIN). This system was the first of its kind in the world and represents state-of-the-art performance in computer-assisted fingerprint identification. The system was funded primarily by federal funds awarded to the St. Paul and Minneapolis police departments by the Crime Control Planning Board, whose staff have worked closely with the two police departments in the design and development of the system. In this report we describe the achievements and problems encountered during the first year of system operation and present ideas on how the system might be improved. For interest of economy in doing the study, we focus on the work of the St. Paul Police Department. The Minneapolis Police Department and the state Bureau of Criminal Apprehension, which also use the system, are considered in less detail.

SYSTEM ACHIEVEMENTS

In the first year of MAFIN operation, the St. Paul Police Department's Crime Lab achieved these results:

- About 90 identifications of criminal suspects were made from latent prints found at crime scenes, and a corresponding number of crimes were solved, the majority of them burglaries--the most difficult of the serious crimes to solve because of the lack of a known suspect in most cases. Very few, if any, of the crimes cleared with the MAFIN system would have been solved without it. The 90 identifications were a 40 percent increase in productivity over the number of latents identified by traditional manual produres--an increase achieved with no added manpower.

- Total identifications increased by 80 percent over the preceding year.

- Additional crimes were solved by investigators following up leads provided by MAFIN clearances. One MAFIN identification led eventually to the solution of thirteen other crimes.

- The value of goods stolen in crimes cleared through MAFIN-aided identifications exceeded $30,000. A significant portion of these goods were returned to the owners and other amounts were recovered through restitution.

- The cost per MAFIN identification and case clearance in St. Paul was about $500. The cost to local taxpayers (for maintenance and operating expenses) was only $100 per identification.

- Crime Lab personnel added almost 3,000 fingerprint cards of new offenders in Ramsey County to the system file. Of this number 170 were identified by MAFIN as having prior arrest records in St. Paul or other agencies, sometimes under aliases.

For the MAFIN system, as a whole, these developments took place:

- The value of the MAFIN equipment increased to $2.3 million from the initial purchase price of $700,000. This increase in value represents a nominal savings of $1.6 million that Minnesota gained by being the first state to acquire such a system. Moreover, about $195,000 per year was saved by negotiating a highly favorable maintenance contract. Over a ten year period these total savings would be $3.6 million, in comparison to current purchase and maintenance costs.

- The system manufacturer, Rockwell International, working with local agencies made major technical improvements in the system; these may increase the accuracy of latent fingerprint identification by over 40 percent. The accuracy of ten-print card identification--already better than that of manual search procedures--was also enhanced.

- St. Paul and Minneapolis purchased a microfiche system and these two agencies have filmed their entire fingerprint card files. This will increase the latent and ten-print card identifications by allowing a rapid access to the files of both Minneapolis and St. Paul by either agency.

- The MAFIN system has gained favorable public attention through newspaper and television

reporting. Within the police departments the system has strong support. The retiring St. Paul police chief, Richard Rowan, cited the system as a major accomplishment of his term in office. Visitors from several states and foreign countries have come to Minnesota to examine the system.

- A high level of cooperation exists among the system users: Minneapolis, St. Paul, and the State Bureau of Criminal Apprehension.

Within the Minneapolis police department and the State Bureau of Criminal Apprehension (BCA) these significant accomplishments have also been made in the first year of MAFIN operation:

- Minneapolis added 7,000 fingerprint cards to its file and discovered 180 persons with multiple criminal records. Twenty-one latent prints from crime scenes were identified. The fingerprint card file was reorganized and many old filing errors were corrected.

- The BCA increased their participation in the MAFIN system and developed plans for improving fingerprint collection in Minnesota. The BCA added over 2,000 cards to the state's computer file and identified six latents from crime scenes.

PROBLEMS AND RECOMMENDATIONS

The users of the MAFIN system are well aware of the problems in system operation, and during the past year they have taken steps to improve the system in many ways. For the most part, the findings of this report have already been communicated to those who work with the system, and the discussion here is intended for a wider audience.

Although there will always be a demand for technical enhancements to the MAFIN system, the best avenue for rapid improvement is in how the system is used. The number of latent identifications that can be attained depends on the accuracy of the computer, the number of latent prints entered into the computer, and their quality. The size and quality of the fingerprint card files are also crucial. Of these factors, the number and quality of latent prints and the card files are largely under the control of local police agencies and the BCA and offer the greatest room for improvement. The system is not being used to capacity, and the potential for latent print collection from crime scenes greatly exceeds what is now accomplished. This is especially true of out-state Minnesota, but also applies to the Twin Cities and suburban area. To collect more latent fingerprint evidence will, however, require a shift in manpower from other police activities. So it is a question of the cost-effective use of resources. In this report we present data on the cost of solving crimes with MAFIN in order that police departments may judge for themselves how MAFIN compares with other police activities as a crime-solving method.

Another simple means to improve MAFIN effectiveness is to make sure that people who have committed crimes are in the fingerprint file. The work of St. Paul shows the value of having juvenile fingerprints on file. Only St. Paul and, to a lesser extent, Minneapolis, however, have extensive juvenile fingerprint card files accessible through MAFIN. In contrast to the philosophy of having as complete a file as possible, the BCA requires submission of fingerprint cards only for adults arrested for felonies or gross misdemeanors, giving the state a file size that is but half that of Minneapolis. This clearly inhibits the value of the MAFIN system, especially to law enforcement agencies outside of Minneapolis and St. Paul.

The issue of fingerprint files and whose records are kept bears on the question of the need for complete and accurate criminal history information. A fingerprint record is essential for the accurate identification of a person and for linking that person to their criminal record, if they have one. Recent changes in the law, namely the sentencing guidelines and the changes in the referencing of juveniles to adult trial court, expand the use of criminal and juvenile delinquency histories in determining how an accused--whether juvenile or adult--is processed or sentenced. This gives new importance to the accurate identification of persons and the accurate linkage with juvenile delinquency and misdemeanor records. At the present time, however, such records are not kept at the state level, nor are they uniformly kept by local police agencies. In other words, it appears that changes in the law imply a need for a more comprehensive identification and record system than is now in place, whether it be at the state or local level.

Although the MAFIN system was designed foremost to identify latent fingerprints, it can also identify persons from their fingerprints taken after arrest, to see if they have a prior record. The MAFIN system has not, in its current use, replaced the traditional identification process for newly arrested persons, but as their fingerprint cards are added to the MAFIN file, a check is made for a prior record. What the MAFIN system adds is the potential (not yet completely realized) for a police agency to search the files of another agency to see if a person has a record in that jurisdiction. Without MAFIN, such a cross-agency identification of persons is not routinely practical.

Absent a central file in Minnesota of juvenile and misdemeanor records, MAFIN is the only practical means to improve our capabilities in checking for these types of prior records. Even if the state moves to expand its criminal history files, MAFIN would still be an ideal way to implement this goal. Thus we see an expanded future role for MAFIN in improving the identification of persons and verifying criminal records, thereby ensuring that the intent of the law is carried out as far as possible.

In 1980 the legislature asked the Crime Control Planning Board to study the future of MAFIN in the state and to make recommendations. Issues that we have raised here will be considered in depth as that study is undertaken.

What we have learned in the course of this evaluation, however, is that unless the state makes a financial commitment to ensure that MAFIN is a statewide system, the level of cooperation between the state and local agencies will almost certainly decline, and the system will become a service available only to the residents of Hennepin and Ramsey counties.

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I. INTRODUCTION

The science of fingerprints took hold in police work when it was discovered that each person's fingerprints (the pattern of friction ridges that flow across the skin of the fingers) are unique. This makes if possible, and relatively easy, to identify fugitives and match up criminals with their prior records. Upon arrest, a person is "finger-printed" by applying ink to his fingers and transferring the fingers' impressions to a card, which then becomes part of his criminal file. Fingerprints are also used outside of the criminal sphere to identify, for example, missing persons, amnesia victims, and unknown deceased.

All of us, everyday, leave impressions of our fingers as we open doors, pick up objects, write checks, drive cars, and touch people. And so it is that criminals often leave a fingerprint at the scene of a crime. This is called a latent fingerprint. It is formed by the transfer of sweat from the finger's ridges to the surface of the object touched. A variety of technical means can make the fingerprint visible. These include dusting with powder, which adheres to the lines of per-spiration, and the application of chemicals which react with constit-uents of perspiration, such as salt or amino acids. The latent print, made visible, is then preserved or photographed as evidence of the crime.

The general public may have the impression from the detectives of television that once a fingerprint is found at a crime scene it is an easy business to catch the criminal. Police investigators know the disappointing truth: That without the name of a suspect whose prints can be compared with the unknown latent, identification is so rare that it is seldom attempted. It is not feasible for an investigator to compare a latent print or "lift" against the hundreds of thousands of fingerprints in a police department's files, even if it were known that the suspect was in the file. In Minnesota alone, tens of thousands of latent fingerprints sit in police files: the print unidentified and the crime unsolved.

Only within the past few years has a solution to the problem of latent identification appeared. With computers and special electronic hardware it is now possible to automate the comparison of a latent fingerprint or inked fingerprint card against a file of millions of fingerprint records, which reside in a computer's memory.

Observing the development of this new technology a few years ago, fingerprint experts from the Minneapolis and St. Paul police departments began to work with the Crime Control Planning Board on the acquisition of an automated fingerprint identification system for Minnesota. By starting early on the long and complex acquisition process, Minnesota became the first state in the country to put into operation this kind of system, in December 1978. Since then similar systems have been installed in Maryland, Texas, California, Brazil, and Canada. All of these systems were manufactured by the Rockwell International Corporation, and they all share key design elements that originated with work at the National Bureau of Standards and the Federal Bureau of Investigation. The FBI has also embarked on a massive effort to automate its fingerprint card identification process, but because of the enormity of the task has not

yet completed it.

The Minnesota system, known as MAFIN, makes it possible to search an unknown latent print from a crime against the fingerprints of over 330,000 persons in the files of St. Paul, Minneapolis, and the state. The system also compares the inked fingerprint cards of newly arrested persons with those in the file, looking for aliases and prior records.

The entire state is served by MAFIN through its three terminals: Ramsey county agencies through the St. Paul Police Department, Hennepin county agencies through the Minneapolis Police Department, and the remainder of the state by the state Bureau of Criminal Apprehension. The central computer site, where the computerized fingerprint files are kept, is at the St. Paul Police Department.

The advent of automated fingerprint identification has excited interest among law enforcement agencies throughout the world. Although the MAFIN system has not completely solved the latent identification problem, it truly is a breakthrough in police work. We have, therefore, thought it wise to evaluate the system carefully, now that it has gone into routine operation, so that the users of the system in Minnesota might learn how to get the most out of the system and that the wider audience might learn from our experiences.

This report looks at the first year's operation of the MAFIN system. In succeeding chapters we describe the system and how it works; we review the acquisition process, and the statistics of the first year of operations; we discuss system performance and cost; and we conclude with an assessment of the MAFIN program, as a whole.

II. THE MAFIN SYSTEM

SYSTEM PHILOSOPHY

The underlying philosophy of automated fingerprint identification is simple: It is to try to duplicate with electronics and computers the process whereby a trained fingerprint examiner ordinarily seeks to identify a fingerprint. The computer, perhaps assisted by a fingerprint expert, locates the position and direction of small identifying marks known as minutiae on an unidentified print and compares them with the minutiae patterns of the known fingerprints in its computer files. The machine is programmed to recognize fingerprint ridge endings and bifurcations (forks) as minutiae.

Fingerprints also fall into broad categories that are named for the general flow pattern of the ridges, such as the loop pattern, the whorl, and the arch. These pattern types are too broad for positive identification of a print, but they are essential to the keeping of fingerprint files. Information about the pattern type of the fingerprint is also entered into the computer and used to organize and search the computer files. We shall say more about the file structure later.

As the computer compares the minutiae pattern of an unknown print with those in its file, it calculates a score for each comparison. Roughly speaking, the score increases as the patterns under comparison look more alike. At the end of the comparison process, the system prints out a list of the file prints that are most likely to have come from the same person as the unidentified print. The fingerprint examiner then takes the list of candidates or "respondents" and visually checks their file cards against the unidentified latent print or card. Thus the computer does not actually identify prints but only assists the examiner by giving him a list of likely suspects. If the print is found to match that of someone on the suspect list, we call it a "hit," otherwise a "miss." Of course, a miss will always occur if the criminal is not in the file.

CONFIGURATION OF SYSTEM COMPONENTS

Keeping in mind the identification process, we can go on to describe the configuration of the MAFIN system. MAFIN equipment is located at three sites: the St. Paul Police Department, the Minneapolis Police Department, and the state Bureau of Criminal Apprehension (BCA) in St. Paul. The St. Paul Police Department is the center of this network, with Minneapolis and the BCA connected to the central site by leased telephone lines.

The St. Paul equipment consists of four major components: a Model 250S Read/Edit terminal, a Print processor, a Search and Match processor, and five 300-megabyte disc drives. These are the functions of the various devices:

- 250S Read/Edit terminal--latent prints and ten-print cards enter the system through this terminal via a high-resolution television camera.
- Print processor--automatically locates minutiae on the latents or cards as they are scanned by the 250S terminal.
- Search and Match processor--selects file prints

from the computer's memory and in four hardware matchers simultaneously compares the minutiae of the unknown print with those of the file prints.

- Disc drives--the minutiae patterns of file prints are stored digitally on magnetic discs; each of the drives has the capacity to hold 100,000 fingerprint cards (persons).

In operation, data starts at the Read/Edit terminal, goes to the Print processor, then to the Search processor, then back again to the terminal, or to a printer for output, upon completion of a task. The processors are somewhat independent of one another, so that if one fails the other may continue its tasks uninterrupted. The Print processor and the Search processor both contain PDP 11/34 minicomputers manufactured by the Digital Equipment Corporation (DEC). These computers organize and schedule the system activities. The mathematical algorithms that locate minutiae and do comparisons are programmed into special purpose electronic hardware (PROMs) because the minicomputers would be too slow to carry out the operations and still maintain an adequate fingerprint processing rate.

At the Minneapolis site, in the Identification Division of the City Hall police headquarters, we have a 250S Read/Edit terminal and a Print processor. (These two components must always go together.) After data is handled by the Print processor it goes to the Search and Match processor in St. Paul over the telephone line. Thus all sites share the single Search and Match processor.

The BCA has only a single terminal that is designed specifically and exclusively for the input of latent prints (not ten-print cards). This terminal is particularly valuable for encoding latent prints of low quality. To enter new fingerprint cards onto the MAFIN file, however, BCA personnel must go to Minneapolis or St. Paul and use the 250S terminal there. Recently, Minneapolis has also added a latent terminal of the type used at the BCA.

MAFIN IN POLICE OPERATIONS

As with any computer, the effectiveness of MAFIN is highly dependent on how well it fits in with the organization of those who use it. So to assess MAFIN properly, we need a picture of how fingerprints are collected and employed in police work.

As we have mentioned, fingerprints enter at two points: 1) when a person is arrested and booked and his fingerprints are taken for identification; and 2) when a latent fingerprint is recovered in connection with a crime.

The general procedure for fingerprint card identification in St. Paul (and, with only slight variations, in most other police identification bureaus as well) is as follows. When a person is booked at the jail, following arrest, his name and other information are recorded and his fingerprints are taken in a "slap" print, that is, the impression of the flat of the hand and all the fingers is taken in its entirety. All of this information then goes to the identification unit where a search is made for a prior record under the name given. If a record is found, the slap fingerprints are compared with the prints on the file card to verify the identity. If no file is found or if the verification fails, the suspect is fingerprinted again; this time his prints are rolled individually onto a standard card. The new card is

classified and searched against the card file. If again no record is found, a new file is started for that person. Additional fingerprint cards are taken and forwarded to the FBI and the state Bureau of Criminal Apprehension, if the crime charged is a felony or gross misdemeanor. (Certain agencies also voluntarily send some misdemeanor cards to the BCA.) The local file card is then passed along to the MAFIN personnel for later addition to the computer file. If the person arrested is not subsequently charged by a prosecutor, the cards may be returned upon request, subject to certain conditions.

If a person is not identified locally, a later identification may be made at the state or federal level. However, it usually takes a couple of weeks for that to occur, which may result in a fugitive being released from custody before his identity becomes known.

In card identification MAFIN has as yet only a secondary role. Being more accurate than the manual process, if may detect a missed identification; or it may find a record in the file of another agency, possibly under an alias. Because the MAFIN system was designed primarily for latent prints, the ten-print identification capacity has not been fully exploited. In the St. Paul Police Department, MAFIN is under the Crime Lab, where latent print work is done, and not in the separate identification unit. Because of organization and equipment location, a second Read/Edit terminal would probably have to be placed in the St. Paul identification unit to automate booking identification.

St. Paul also maintains a limited juvenile fingerprint card file. Generally, a juvenile's fingerprints are taken only if he is arrested for a felony or a gross misdemeanor, and the card may be returned to the juvenile if he is not formally charged. This file is very important to the MAFIN system because of the number of hits made on juvenile suspects.

Latent fingerprints reach MAFIN by several routes. They may be lifted at a crime scene by a patrol officer or by a fingerprint expert, or they may be recovered in the Crime Lab from objects involved in a crime. Fingerprints left on paper, as in check frauds or forgeries, for example, require laboratory methods to be revealed. St. Paul is different than most agencies in that they rely heavily on patrol officers, who are the first to respond to a crime, to search for latent prints. Other agencies, as Minneapolis, rely primarily on specialists trained in physical evidence collection. Although the collection of latents by patrol officers has the potential for greatly increasing the number of latents collected by an agency, there may also be a loss of quality in evidence collection compared to that of evidence technicians.

If a latent is of good quality and there is no obvious suspect against whose prints one might do a manual comparison, the latent will be entered into the MAFIN system by a fingerprint expert. If an identification is made, the name of the suspect is referred to the detective responsible for the case. The fingerprint examiners may also check the suspect's prints against those found at similar recent crimes, or follow-up leads concerning known associates of the suspect. In this way a MAFIN hit may lead to the solving of other crimes through traditional investigative practices.

If MAFIN fails to identify a suspect, the latent automatically enters a computer file of unsolved crimes. Later, as new cards are added

to the file, MAFIN will check them against all of the latents in the unsolved crime file. Thus it is possible, and indeed has happened, that a person may commit several crimes before being arrested and fingerprinted, but latents from the earlier crimes will be identified upon his arrest. Latent prints too poor in quality for MAFIN are saved and filed, as they may yet be adequate for manual identification should a suspect be named.

Although the MAFIN system fits quite well into the ordinary flow of police work, it does introduce some strains in the organization. The system has put a new emphasis on the quality of fingerprint cards and latent lifts and on the quantity of latents received. Quantity and quality are both needed for the system to be most effective. However, these aspects of fingerprint work are largely outside the control of those immediately responsible for operating the MAFIN system. Thus communication and coordination among the several units and patrol officers are necessary for a successful system.

MAFIN OBJECTIVES

In planning for the MAFIN system, fingerprint experts expected the system to make significant contributions in a number of areas of police work--areas where MAFIN has unique capabilities. These objectives for MAFIN prompted the purchase of the system and continue to stand as dimensions for evaluation.

1. Foremost among objectives is the clearance (solving) of routine criminal cases. Burglaries, for example, ordinarily have a very low clearance rate (about 13 percent), yet estimates suggest that latent evidence can be collected in about half of all burglaries. Thus MAFIN offers the potential to solve many crimes that are not now being solved.

2. Experience suggests that every year police departments are faced with a small number of exceptional crimes that consume much time and expense in investigation: a murder, for instance, or a string of serious crimes by the same suspect. Often fingerprint evidence exists for these crimes. The prospect is that from time to time MAFIN will produce a suspect early in the investigation and thereby yield a large savings. A single instance might well "pay" the cost of operating MAFIN for an entire year.

3. Because MAFIN can identify latent prints very quickly, in a matter of minutes or hours, it is possible to recover stolen goods before the thief or burglar has time to sell or conceal them. The aim, therefore, is to ensure that the investigation process exploits this machine capability.

4. Latent prints from unsolved cases may be identified in the future when the perpetrator is arrested and his fingerprints added to the computer's file.

5. The MAFIN system provides a check on the manual identification of arrested persons and offers the capability to search for aliases and prior records across agencies. This ought to improve the accuracy of criminal history information and reduce the chances of fugitives being unwittingly set free.

6. The existence of MAFIN may, in itself, encourage the collection of fingerprint evidence, where in the past it was often neglected for want of a suspect, and stimulate an improvement in the quality of fingerprint work throughout the state.

As we review MAFIN's first year of operation we shall consider to what degree these objectives have been met.

III. SYSTEM ACQUISITION AND DESIGN

THE NEED FOR LATENT PRINT IDENTIFICATION

Minnesota's police agencies first took an interest in automated fingerprint identification in about 1975. The primary motive was, and continues to be, the large quantity of latents (or lifts) that are collected at crime scenes. The St. Paul Police Department, for example, had embarked on an ambitious program to train squad officers in the collection of latent prints and other physical evidence at the scene of a crime. As a result of this and other evidence training programs in the state, the number of latents being brought in from crime scenes had greatly increased over earlier years. St. Paul alone now collects over 10,000 latents annually.

Of course, not all of these prints are of sufficient quality to make identifications, but within this large number we expect to find many--perhaps several thousand--that are. It was this rapidly increasing volume of fingerprint evidence, coupled with the extreme difficulty of identifying more than a few percent of them, that prompted the call for improvements in the identification process.

ACQUISITION OF THE SYSTEM

In Table III-1 we set forth a chronology of the major events that took place in the development of the MAFIN system. Starting in 1975 and 1976 the staff of the Crime Control Planning Board and fingerprint experts of the Minneapolis and St. Paul police departments began the search for an automated fingerprint identification system that would meet Minnesota's needs. After evaluating several types of systems, we decided that only a minutiae-based system was capable of achieving the required accuracy and speed. Furthermore, our analysis of test results on the prototype or laboratory minutiae-based systems convinced us that an automated system would be cost-effective at producing latent identifications when compared with manual procedures. The problem was that no one had actually built such a system; most of the ideas were still on the drawing board.

Once it was decided that the Crime Control Planning Board would award federal and state funds for the purchase of an automated latent fingerprint identification system, the city of St. Paul on behalf of themselves and Minneapolis requested bids for a system. Only two vendors responded, Calspan and Rockwell International, both of whom had worked with the FBI on the problem of automated fingerprint card identification. The bid was awarded to Rockwell International. This began a long period of system development that continues even today during which we in Minnesota have worked closely with electrical engineers and computer architects at Rockwell to design the system.

TABLE III-1

MAFIN CHRONOLOGY

TIME PERIOD	EVENTS
1975 through 1976	The Crime Control Planning Board (CCPB) and local police agencies identify the need for improved latent fingerprint identification; vendors of identification systems are interviewed; system requirements are defined.
September, 1976	Prototype systems are tested at Calspan and Rockwell International by Minneapolis and St. Paul police departments.
January, 1977	CCPB staff recommends a grant for purchase of an automated latent fingerprint identification system on the basis of test results, needs assessment, and cost-effectiveness study.
February, 1977	The city of St. Paul issues a bid (No. A7208) for purchase of the system.
March, 1977	Rockwell is awarded the bid at a contract price of $763,300.
April, 1977	The CCPB awards grants to St. Paul and Minneapolis for the system; the BCA receives a terminal to ensure statewide coverage.
September, 1977	System design review at Rockwell, Anaheim, California with MAFIN users.
January through September, 1978	Fingerprint cards from the state are shipped to California for encoding via high-speed readers.
February through March, 1978	Negotiations on system delays and design problems held; Rockwell changes project management.
October through November, 1978	Acceptance testing in Anaheim; system accepted; site preparation in Minnesota.
November, 1978	System delivered and installed.
November, 1978	CCPB awards second year funding to Minneapolis.
February, 1979	System becomes operational: the first of its kind in the world.
September, 1979	The 100th latent print is identified with MAFIN.
September, 1979	An International Users' group is formed.
December, 1979	CCPB awards third year grant to Minneapolis.
December, 1979	System improvements made; R40 matcher added.

The total project cost as cited in the grants awarded was $827,407, divided between Minneapolis and St. Paul. The terminal at the BCA was essentially donated to the BCA for their use in order to make the system truly statewide. They did not participate in the grant process. The sale price of the system was $763,300. This included the equipment, the computer encoding of the entire fingerprint card files of Minneapolis, St. Paul, and the BCA, and twenty-one months of maintenance at $52,500 (to follow the initial 90 day warranty period). The difference between project cost and purchase price was due to the need for travel, telephone service, site preparation, and so forth. The St. Paul Police Department absorbed additional installation costs not reflected in the grant awards.

Because this Minnesota system was the first to be purchased, competition between the two vendors was keen; the prospective market did not support two vendors. As a result, Minnesota was able to negotiate a very favorable sales price and a long-term maintenance agreement. The contract specifies that maintenance is available at $30,000 per year, adjusted for inflation, for up to ten years. Rockwell would now charge at least $2.3 million for the same system, and the usual maintenance cost is one percent of the purchase price per month. Over a ten year period Minnesota will have saved $3.6 million (constant dollars) in comparison to current purchase and maintenance costs.

The decision to purchase the system was based on the level of performance observed during testing. The request for proposal, however, specified our desire for a system of higher accuracy and speed, in order to stimulate further technical development. Both vendors did

offer systems that, they anticipated, would meet the proposed high standards. In retrospect, however, it is clear that the vendors' responses were overly optimistic and not based on achieved results. To guard against this possibility the contract included a penalty clause for failure to meet the proposed level of performance. In the end the system manufactured by Rockwell was accepted, but a (maximum) penalty of $75,000 was charged against Rockwell. This money was later used to make improvements in the system.

The fact that Rockwell could not meet the contract requirements in full came under mutual discussion before the system was accepted. After a period of negotiation, Rockwell offered certain concessions. First, as the system delivery date was delayed, Rockwell offered an additional disc drive, having a value of about $20,000. This gave the system the capacity for an additional 100,000 persons on file or the availability of the unit as a back-up to one of the other four disc drives. (To date it has been used as a back-up.) Additionally, to keep the speed of the system at the contract level, Rockwell added two high-speed matchers to the two originally called for, giving the current system four matchers capable of about 200-250 comparisons per second of a latent print against a file print.

SYSTEM DESIGN CONSIDERATIONS

The design of a system as complex as MAFIN requires many hard and irrevocable decisions. These decisions involve trade-offs among the purpose, cost, speed, and accuracy of the equipment. Going beyond technical concerns, the system designer must also deal with the problems of merging a highly technical system into a human organization.

I shall review here the major design decisions that affected MAFIN development.

To summarize the design process, these were the issues to be resolved:

1. The orientation of the system toward latent identification rather than ten-print card identification;
2. The file size and structure;
3. The limits on the number of minutiae to be encoded for each finger from the ten-print file cards;
4. The number and type of descriptive items to be stored on the computer with the minutiae for each file print;
5. The kind and number of subfiles;
6. The match rate, ie., the rate at which the machine can compare a latent against file prints;
7. The use of automatic classification of cards as they are entered onto the system;
8. The number and location of terminals in the system.

The first of these issues, the orientation of the system to latent print identification, was the first major decision reached. It was based on the much greater need for improved latent identification than improved card identification in the police agencies. By and large, the traditional card identification process works quite well and automation did not appear to offer cost savings in this area that would justify purchase of the system.

Technically, the decision to have a latent-oriented system has had its greatest impact on the storage of the fingerprint files on the

system's disc memories. In the Minnesota system the file structure is organized on individual fingers, which are arranged by the standard NCIC pattern type and finger number. (The NCIC code is a national classification scheme used to classify fingers, as opposed to the older Henry system that classifies cards according to the distribution and type of patterns of all the fingers of a person.) When a ten-print card for an individual is added to the computer file, the ten fingers are not kept together in the same part of the memory, but instead are distributed in accordance with pattern type. The advantage of this file structure is the speed it allows when searching a latent against large files, given that the operator is often able to discern the pattern type of the latent and use that information to narrow the computer's search. When a ten-print card is searched against the file, two of the ten fingers are used for comparisons as if they were latent prints.

Along with each finger's minutiae pattern, the computer file also contains an identifying number, a microfilm (microfiche) address for locating the original ten-print card, year of birth, sex, and race. Also included in the file with each finger is the NCIC classification code for the person's entire ten fingers. The purpose of this redundancy is to speed the searching of latent clusters and ten-print cards. The NCIC code is also converted into a Henry classification when the final suspect list is printed out to aid the fingerprint expert in finding the original fingerprint card in the physical card file.

The system has varying limits on the number of minutiae encoded for the fingers--up to 150 may be encoded for the first three fingers of each hand; 100 for the fourth; and 75 for the fifth. These fairly high limits show again the latent-orientation of the system. Fewer minutiae are needed in a system used exclusivly for card identification because the knowledge of all ten fingers makes the search for a match so much easier.

The file structure also incorporates subfiles. A separate subfile exists for adults, juveniles, and police officers. Furthermore, each of the three agencies using the system has its own set of files, although not necessarily all of the subfiles are used. Provisions were made to allow new agencies to join the system with separate files at some future date. If an agency must purge a record from its file, this is done without affecting the files of the other agencies.

The decision to have (at least) three agencies using the system was made to ensure that all law enforcement agencies in the state have access to MAFIN. Each of the three agencies has the required expertise in fingerprint work and maintain fingerprint card files. The system has the capacity for several more terminals or agencies to be added to the system should the need be demonstrated.

Another important design decision to be decided early on was the match speed. In all fingerprint identification systems there is a trade-off between speed and accuracy. Higher accuracy goes with more complex matching procedures, or algorithms; but the more complex algorithms also eat up more computer time. The total number of identifications that a system can make over the long run depends on both accuracy <u>and</u> speed. The Minnesota system was designed to favor speed over accuracy--a choice well suited to agencies with a large supply of latents. The high match rate, at 200-250 comparisons per second, is

necessary as well to accommodate three agencies sharing the system. In practical terms, this match rate means that a ten-print card can be identified within a few minutes while a latent may take anywhere from fifteen minutes to a few hours depending on what portion of the file must be searched.

Another important design decision was not to purchase an automatic classifier for ten-print cards. The MAFIN users concluded that the technology of automatic classification was not yet advanced enough for reliable automatic classification and that it was not essential for a latent-oriented system.

RECENT SYSTEM DEVELOPMENT

During the first year of MAFIN operation a number of changes were made in the system; three are of special note. The first was the inclusion of automatic cross-referencing when ten-print cards are searched against the file. Because fingerprint examiners are not uniformly consistent in classifying cards, a person's prints may be classified differently on separate occasions. The result may be that a person's previous record is overlooked and a second or third file started. To get around these problems, the computer is programmed to check alternative classifications in the instances where ambiguity in classification is most commonly observed.

A second enhancement is the "R40" matcher. At the operator's option, an additional matching step is now available to improve the accuracy of a latent or ten-print match. Because this is a slow matching process only those comparisons which have the highest scores through the normal matching process (the "R30") are sent to the second stage.

The test results by Rockwell indicate a potential improvement of 40 percent in the number of latent hits.

Also significant is the purchase of microfiche equipment by Minneapolis and St. Paul. Both agencies have filmed their card files, putting 600 cards on a single microfiche. Each agency has copies of the other's file, allowing a visual comparison of a latent or card against any file card of the two agencies in only a few seconds. This compares with as much as 5 to 10 minutes previously required for a manual verification.

IV. THE FIRST YEAR OF OPERATION

In this chapter we summarize the first year of MAFIN operations for St. Paul, Minneapolis, and the state. Further analysis of the operational statistics for St. Paul gives a picture of current system usage in relation to the potential capacity of the system for processing fingerprints. Additional benefits gained by MAFIN operations are also discussed.

SUMMARY STATISTICS

System users have gathered data on both their latent work and ten-print card operations. The average monthly rates at which latents and cards are processed by the system are shown in Table IV-1. The BCA is the most active at card entry (650 per month) followed by Minneapolis (582 per month) and St. Paul (328 per month). The total number of cards added to the system file annually is about 18,700. In latent work, St. Paul is the most active (47 per month) followed closely by Minneapolis (43 per month). The BCA processes a much smaller number of latents (9 per month). Total latents searched by the system over a year we estimate at about 1,200. A given latent may be entered or searched several times, however, so that actual system usage for latent work is greater than these numbers suggest.

TABLE IV-1

AVERAGE TEN-PRINT CARD AND LATENT ENTRY PER MONTH FOR THE THREE OPERATING AGENCIES

OPERATING AGENCIES	CARDS PER MONTH	LATENTS PER MONTH
St. Paul	330	47
Minneapolis	580	43
Bureau of Criminal Apprehension	650	9
TOTAL	1,560	100

Because the BCA usually uses the Minneapolis terminal to enter its cards, the Minneapolis site is processing about 1,230 cards per month. This rate is sustained by operating the system continually over three shifts each day. The BCA personnel fit their card entry work into the Minneapolis day shift. This is far from an ideal procedure, however, and the BCA has a considerable backlog of over 1,000 cards to enter. In addition, transportation and scheduling are constant problems for BCA personnel.

In Table IV-2 are the number of latents retained by the departments, the percentage of those latents searched on the MAFIN equipment, and the hit rate for the latents searched. The Minneapolis data for the first two of these items are, however, only a rough estimate. This table shows that St. Paul has been the most successful at identifying latents, having a hit rate of around 11 percent. This is twice the rate of the other two agencies. More recent data, for the first quarter of 1980, show a greater equality in hit rate among all three agencies, at about 7 percent; nevertheless, it is hard to judge whether the trend of a single quarter will continue.

TABLE IV-2

LATENTS RETAINED, THE PERCENTAGE OF RETAINED LATENTS SEARCHED BY MAFIN, AND THE HIT RATES FOR THE USER AGENCIES

OPERATING AGENCIES	LATENTS RETAINED PER MONTH	PERCENT OF RETAINED LATENTS SEARCHED	LATENT HIT RATE	NUMBER OF LATENT HITS IN FIRST YEAR
St. Paul	260	19%	11%	95
Minneapolis	200[a]	22%[a]	4%	21
Bureau of Criminal Apprehension	94	9%	5%	6

[a]Rough estimate from incomplete data.

From the percentage of retained latents searched on MAFIN one can get a sense of the quality of latents collected. These rates are useful in assessing how the collection of latents may affect system usage.

A breakdown of the first 100 hits on the system gives some explanation of why St. Paul was more successful than the other agencies. Of the 100 hits, 79 were by St. Paul. Of these 79 hits, 42 (or 55 percent) were for juveniles. In contrast, only 6 of 19 Minneapolis hits were of juveniles and none of the BCA's were. The explanation for the difference clearly seems to be the relative sizes of the juvenile card files of the three agencies. At that time St. Paul had a file of 2,200 juveniles, Minneapolis 650, and the BCA none. Thus agency policies in the collection of fingerprint cards on juveniles have a great bearing on the effectiveness of the system.

Another finding is that 22 percent of St. Paul's hits were made on the unsolved latent file; that is, the identification was made when after the person was arrested and his card added to the file, it was found to match a latent collected from an earlier unsolved crime. All of the hits in the unsolved latent file (17 in St. Paul, 1 in Minneapolis) were of juveniles, showing again the significance of the juvenile file.

An analysis of the first 100 hits also reveals the types of crimes most likely to be solved by MAFIN. Burglaries comprised 65 percent of the crimes, auto thefts 16 percent, other theft 8 percent, robberies 5 percent, and forgeries 2 percent.

ANALYSIS OF ST. PAUL'S OPERATIONS

During the first few months of 1979, immediately after MAFIN began operating, St. Paul made a concerted effort to search latent prints on the MAFIN system. With a backlog of thousands of latents from unsolved crimes it was easy for St. Paul's fingerprint examiners to cull out good quality latents and search them. In other words, the first few months of MAFIN use in St. Paul were not typical of later system usage but do show what the system can accomplish if a very large quantity of latents is available. This initial high activity period thus tells us about the capacity of the system.

At a peak, about 150 latents were entered in the St. Paul site in a month. Of this number 15 percent were identified. The St. Paul Crime Lab operates only a single day shift; so all latent work was done within eight to ten hours each day. The 15 percent hit rate is double the most recently observed hit rate, which shows again that the hit rate is not simply a function of machine performance but also reflects quality of latents searched. The 47 latent per month rate cited above (Table IV-1) is an average of the "steady-state" operation after the peak months; in comparison with the peak rate the St. Paul site is now operating at 31 percent capacity for latents.

In judging a 15 percent (or other) hit rate one must consider that perhaps only half of all criminals are in the file and that the St. Paul Police Department does not routinely take elimination fingerprints from crime victims. That is, some of the latents searched undoubtedly were victim prints or completely unrelated to the crime. So one might conclude that at its peak efficiency MAFIN was identifying at a rate of 1 in 3, or better, of criminals in the file.

In general, the hit rates of the three agencies also reflect their policies of verification. The number of suspects in the MAFIN-generated list that are manually checked is closely related to the hit rate. From statistical tests we know that roughly half of the hits will be between the 10th and 100th places on the respondent list. Yet because of the time involved in manual verification, it has been the practice that only the top five or so suspects are checked. The odds of getting a hit decrease rapidly as one moves down the respondent list from first place; so it is a good strategy to limit the manual verification at some point. It was this knowledge that many hits, perhaps half or more, were being missed in the manual verification process that prompted Minneapolis and St. Paul to purchase a microfiche system that will allow a rapid visual examination of photographs of cards in the file.

The number and quality of inked ten-print cards in an agency's file are important to MAFIN success. We do not have any specific data, however, on the quality of cards in Minnesota. The number of adult and juvenile cards in the files of the three agencies, in July, 1980, are shown in Table IV-3.

TABLE IV-3 FILE SIZES OF THE MAFIN USER AGENCIES[a]		
OPERATING AGENCIES	ADULT	JUVENILE
St. Paul	63,702	2,444
Minneapolis	168,234	908
Bureau of Criminal Apprehension	96,057	0

[a]Multiply by ten to obtain number of individual finger records in computer file.

CASE CLEARANCES

Prior to MAFIN's operation various questions existed about whether MAFIN hits would lead to case clearances as readily as traditional manual identifications and whether there would be any problem in court using MAFIN-assisted identifications as evidence. Although we have not conducted an exhaustive analysis of all cases where a MAFIN hit was involved, MAFIN users have not yet encountered any unusual problems in case clearance or evidentiary matters. This holds even for cases that were one or two years old by the time MAFIN identified the suspect. Apparently, the weight of fingerprint evidence at a crime scene is so strong against a suspect that guilty pleas are routine.

Almost all of the MAFIN hits identified at least one perpetrator involved in a crime. In this sense, we can consider the hit as having led to a case clearance. Not all clearances led to conviction, however, or even to charging of the suspect. In one instance of a particularly serious crime, the victim was unwilling to file a complaint. In a number of the cases where MAFIN identified a suspect, it was possible for fingerprint examiners to identify manually additional suspects, using their knowledge of the first suspect's known associates. In other cases,

the MAFIN hit led to a suspect whose prints were then manually checked against those found at similar crimes. Through such procedures MAFIN identification of a car thief led eventually to the clearance of thirteen crimes. Although we have not made an exhaustive study of case clearances in relation to MAFIN hits, it appears that the number of cases cleared either directly or indirectly is at least as great, if not more, than the number of MAFIN hits.

If we operate under the rule that a hit equates with a clearance, we can estimate the impact of MAFIN on total case clearances. Of the various crime types, MAFIN has its greatest impact on the solving of burglaries, which traditionally have been the most difficult of the serious crimes to solve. Burglaries, among the serious crimes, are the least likely to have a known suspect, while at the same time they are very likely to have latent prints from the perpetrator because of his extensive activity during commission of the crime. St. Paul had 91 hits during 1979 of which we estimate 62 were burglaries. (We base this estimate on our analysis of the first 100 hits, for all agencies, which included 68 burglaries.) In 1979 St. Paul reported 7,135 burglaries. Thus 62 of the 7,135 or about 1 percent of the burglaries were cleared with MAFIN. Of the 7,135 burglaries, 748 were cleared by other means. So MAFIN increased the number of burglary clearances by about 9 percent. We should also note that this increase was achieved with no increase in manpower.

The value of goods stolen in MAFIN-cleared crimes (excluding auto thefts) exceeded $24,000 in 1979. In the 42 cases where the value of lost goods was reported, the average loss was $580. The total amount recovered is not known, but we have accounts of several cases where the MAFIN identification was made soon after the crime and led to recovery of the stolen goods in the possession of the criminal. The total value of recovered goods for these cases was several thousand dollars. These cases demonstrate the capability of MAFIN for the speedy solution of crimes, which was one of the initial objectives for the system. The recovery of stolen goods in possession of the criminal is also instrumental in prosecution of the case.

Another of the goals of the system was the solving of exceptional crimes that might have consumed substantial investigative resources. In 1979 no exceptional crimes were solved in Minnesota using MAFIN. The prospects for this are good, however, if we judge by the experience of other cities. Canada, California, Maryland, and Houston all report the solving of murders with their systems.

In 1979, St. Paul made 246 identifications manually and 91 with MAFIN. Because MAFIN hits were in cases where the suspect was unknown to the police, the MAFIN hits represent an increase in productivity for the Crime Lab of 37 percent over what would have been accomplished without MAFIN. (All manual identifications involved a known suspect.) This increase was made with no added personnel. Total identification by the St. Paul Crime Lab increased by 80 percent over the preceding year. Thus the operation of the MAFIN system did not detract from the capability of the Lab to do manual identification.

In this chapter we have reviewed the statistics for the first year of MAFIN operation. They show that the system has made a modest improvement in the solving of crimes, especially burglaries. The data

also points to the fact that the system is not being used to capacity and that an even greater impact on crime might be achieved. In the next chapter we examine more closely the factors related to MAFIN performance levels.

V. TECHNICAL EVALUATION

PROJECTED AND ACTUAL LATENT IDENTIFICATION

One of the most important and frequently asked questions about the MAFIN system is, "How well does it work?" Unfortunately, this is not an easy question to answer. There are two approaches. One can test the system in a controlled manner, or one can simply report the hit rate of the system in its normal operation. Although the controlled test gives a definitive and repeatable result, this result may have little bearing on how well the system performs in everyday use. On the other hand, many factors affect the hit rate of the operational system, and the hit rate only partially depends on the capabilities of the equipment. In evaluating MAFIN we have followed both approaches.

The contract for the purchase of MAFIN called for an acceptance test. In this test we conducted a controlled trial of the machine's accuracy. A sample of 92 latents from actual crime scenes were entered into the system. This was not a random sample of crime scene latents, but was required by contract to average 16 minutiae per latent. These latents were then searched against a file of 10,700 fingerprint cards, or 107,000 separate fingers, known to contain the fingerprints matching the latents. The outcome of the test is shown in Table V-1, under the column "R30." The table entries are how the computer ranked the correct match among the 107,000 possible matches. In 16 percent of the cases the computer's first choice was correct. In 29 percent of the cases the

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correct match was in the top ten, while about 50 percent of the latent's were in the top 100 of the 107,000, by the computer's ranking.

TABLE V-1

TEST RESULTS ON LATENT IDENTIFICATION

RANK IN RESPONDENT LIST	PERCENT OF TEST LATENTS CORRECTLY IDENTIFIED AT THE RANK: R30	R40
1st place	16%	30%
1st to 5th	22%	39%
1st to 10th	29%	42%
1st to 20th	32%	42%
1st to 100th	49%	49%

Later, Rockwell retested the same latents with the new matching algorithm R40 added to the R30. The results of the combined R40/R30 test are also given in Table V-1. The effect of the R40 matcher is to shift low ranking hits, which would likely be missed in practice, to near the top of the respondent or suspect list.

Because the R30 matcher of the acceptance test was the same as used in the earlier prototype testing, the acceptance test results were much like those previously observed. Thus the decision to purchase the system based on the prototype testing was not altered by the fact that the acceptance test did not meet the contract performance level; the penalty of $75,000 was invoked as compensation for failure to meet the contract.

Based upon our prototype testing an operational hit rate of about 15 percent for latents was projected, assuming that the matching print is in the file and that only the computer's top five suspects are

verified manually.[1] The 15 percent hit rate was a compromise between a 19 percent rate observed in our test and a 14 percent hit rate projected from test data of Scotland Yard on the same system. Because the latter had done more extensive testing, we weighted the final projection, conservatively, toward their result.

To estimate the likelihood that the suspect is actually in the file we used data on the rearrest rate in St. Paul. About 60 percent of adults arrested are found to have prior records; so we took this figure as a proxy for the chance of a suspect being in the MAFIN file. To convert the projected 15 percent hit rate with a known match in the file to the operational rate, we multiply $0.15 \times 0.6 = 0.09$, or a 9 percent hit rate. The range 14 percent to 19 percent of the prototype testing then becomes 8 percent through 11 percent for the operational system.

As observed in Chapter IV, Table IV-2, the hit rate for latents in St. Paul was 11 percent if hits on the unsolved latent file are counted, or 9 percent if not counted. So the observed hit rate is about the same as that projected from the early test results on the equipment.

In the decision to purchase the system we also projected the total number of latents that might be identified in one year at the St. Paul site. Although the hit rate projection turned out to be close to the mark, the projection of total hits was overly optimistic. It was estimated that of the latents collected annually, 3,500 would be searchable on the system. At a hit rate of 9 percent, 315 hits would be made. This contrasts with the 95 hits obtained in the first year of St. Paul's

[1] Crime Control Planning Board memo, dated November 8, 1978, from S. Coleman to Robert Crew, Executive Director, "Latent Fingerprint Identification: System Test Results and Operational Evaluation."

operation (Table IV-2).

As data presented earlier shows (Table IV-2), latents are now being entered on the St. Paul terminal at the rate of 47 per month, or 560 per year. If MAFIN were operated at the peak load seen in early 1979, namely, at 150 latents per month, and if the hit rate were 15 percent, as it was in early 1979, the system would produce 270 latent hits per year. So given sufficient supply of latents the system can operate close to the expected level. That it has not done so implies a lack of latents of adequate quality.

Table V-2 presents the number of latents collected and retained from the three sources of latents in St. Paul, namely, the Crime Lab, the squads, and other non-St. Paul police agencies in Ramsey County. This data shows a sharp drop from 1978 to 1979 (when MAFIN began operating) in the number of latents collected by the patrol squads. The percentage of squad latent lifts retained also dropped, from 30 percent to 20 percent, suggesting a decline in quality as well as quantity.

TABLE V-2

LATENTS RECOVERED AND RETAINED BY ST. PAUL SOURCES DURING 1979 AND (BEFORE MAFIN) 1978

YEAR	CRIME LAB LATENT LIFTS	SQUAD LIFTS	SQUAD LIFTS RETAINED	PERCENT SQUAD LIFTS RETAINED	OTHER AGENCY LIFTS	OTHER AGENCY LIFTS RETAINED	PERCENT OTHER LIFTS RETAINED
1979	1,094	8,098	1,660	20%	880	354	40%
1978	1,306	8,919	2,689	30%	922	391	42%

Crime lab personnel attribute the decline in latent work to the inception of team policing in St. Paul and to the shifting of priorities from evidence collection to improved response time or other aspects of police work. Because the number of latents collected by squads has

fallen below expectations, some consideration is being given in St. Paul to a return to the use of technicians in crime scene investigations.

TEN-PRINT CARD IDENTIFICATION

In general, the results of card identification have been impressive. It is the judgment and experience of MAFIN users that the system is more accurate than the traditional manual card identification process. Minneapolis, for example, has found duplicate or alias records in 2.6 percent of the cards entered into its file. Accuracy has been further enhanced by the R40 matcher. Although intended primarily for latent work, the R40 can also be used in the ten-print mode. The use of alternate referencing, as discussed previously, has contributed to card identification.

The identification of persons who have records in other agencies is also increasing and will accelerate when the microfiche equipment is fully used. By the end of 1979 about 12 percent of the cards added to the St. Paul file were discovered to have prior records in other jurisdictions.

DISCRIMINANT ANALYSIS

To analyze further what factors have the greatest bearing on whether or not a latent print will be identified by the computer, we have employed a statistical procedure called discriminant analysis. The method is to compare, statistically, latent prints that resulted in hits with those that did not. Of course, the fact that a latent is not identified may be because the suspect is not in the file. So some of the unidentified latents will have characteristics similar to those that are hits. Nonetheless, discriminant analysis has sufficient statistical power to detect differences between hits and misses for latents when the suspect is in the file.

The analysis proceeded with the collection of data on 35 identified latents and a sample of those not identified. Since data on missed latents had not been saved routinely, the sample size of unidentified latents is only 21. Although more than 35 latents have been identified, we restricted the analysis to a subset of St. Paul's hits. Excluded were identifications on the unsolved latent file and those made on an earlier scoring system. Furthermore, only first place hits were considered.

To predict whether or not a latent is likely to be identified, we examined four variables: 1) the number of minutiae encoded from the latent; 2) the number of comparisons made by the computer, that is, the portion of the file searched; 3) the pattern type of the latent--loop, whorl, arch, or unknown; 4) the highest score on the respondent or suspect list. The last of the four is chosen in order to make the score as comparable as possible for hits and misses. This also reflects our restriction to first place hits. The restriction, incidentally, is no great drawback to the analysis because hits are far more likely to be in the first place of the respondent list than at any other place.

As it turns out, the second variable, the number of comparisons, has a not very normal distribution among the latents and better results are obtained by transforming this variable to its logarithm (base 10). The effect of using the logarithm is to give less weight to very long searches, when hundreds of thousands of comparisons are made. This implies that increases in the number of comparisons have a diminishing

effect in reducing the hit rate as the number of comparisons become very large. In citing statistics for the sample of latents, we shall give the original variable instead of the logarithm for greater clarity.

The discriminant analysis shows that of the four variables initially included, the number of minutiae is the most significant followed by top score and comparisons made. The pattern type was of questionable significance, which is understandable in that the number of comparisons already incorporates knowledge about the rarity of the pattern. (The first three variables are statistically significant at the $p < .001$ level.) In Table V-3 we report the means and standard deviations of the significant variables.

TABLE V-3

STATISTICAL CHARACTERISTICS OF LATENTS USED IN THE DISCRIMINANT ANALYSIS

	AVERAGES		STANDARD DEVIATIONS	
VARIABLE	Hits	Misses	Hits	Misses
Number of minutiae	21.4	17.0	4.9	4.5
Number of comparisons	76,500	86,200	107,000	66,000
Top score	2,630	2,570	549	628

The discriminant analysis constructs a classification rule based on the significant variables. This rule can help us to predict whether or not a latent is a first-place hit, given the values of the three variables. Applied retrospectively to the latents analyzed, the classification rule gives the results in Table V-4. Overall, correct "predictions" occur in 86 percent of the cases (48 of 56). We might compare this with our success had we predicted a hit in every case, which would yield only a 60 percent success rate. The instances where the rule predicts a miss, yet where there was actually a hit, seem to have a number of comparisons substantially larger or smaller than average; it may be that even transformed this variable needs more refinement.

TABLE V-4

RESULTS OF USING THE DISCRIMINANT ANALYSIS CLASSIFICATION RULE TO "PREDICT" HITS AND MISSES

PREDICTED (a posteriori)	ACTUAL Hits	ACTUAL Misses
Hits	29	2
Misses	6	19

$n = 56$; $\chi^2 = 28.6$; $p < .001$

The classification rule for predicting first-place hits and misses is as follows: The value of each of the three variables is multiplied by a specific constant; the products are then added or subtracted as the sign of the constant indicates. If the total exceeds a threshold value, a first-place hit is predicted; if not, a miss. Thus we have, approximately:

$$\begin{array}{rl} 0.003 & \times \text{ top score} \\ +\ 0.5 & \times \text{ number of minutiae} \\ -\ 1.3 & \times \log \text{ (number of comparisons)} \\ \hline & \text{TOTAL} \end{array}$$

If TOTAL > 11.8, we predict a first-place hit.

If one wishes not to use the logarithm, a classification rule of nearly the same accuracy (81 percent) may be constructed. For each 10,000 comparisons subtract 0.1 instead of the quantity above, and set the threshold at 16.3.

This rule was checked against a small number (11) of additional first-place hits not included in the discriminant analysis. The outcome was as follows: Of the 11, 8 were predicted as hits, 2 had scores near

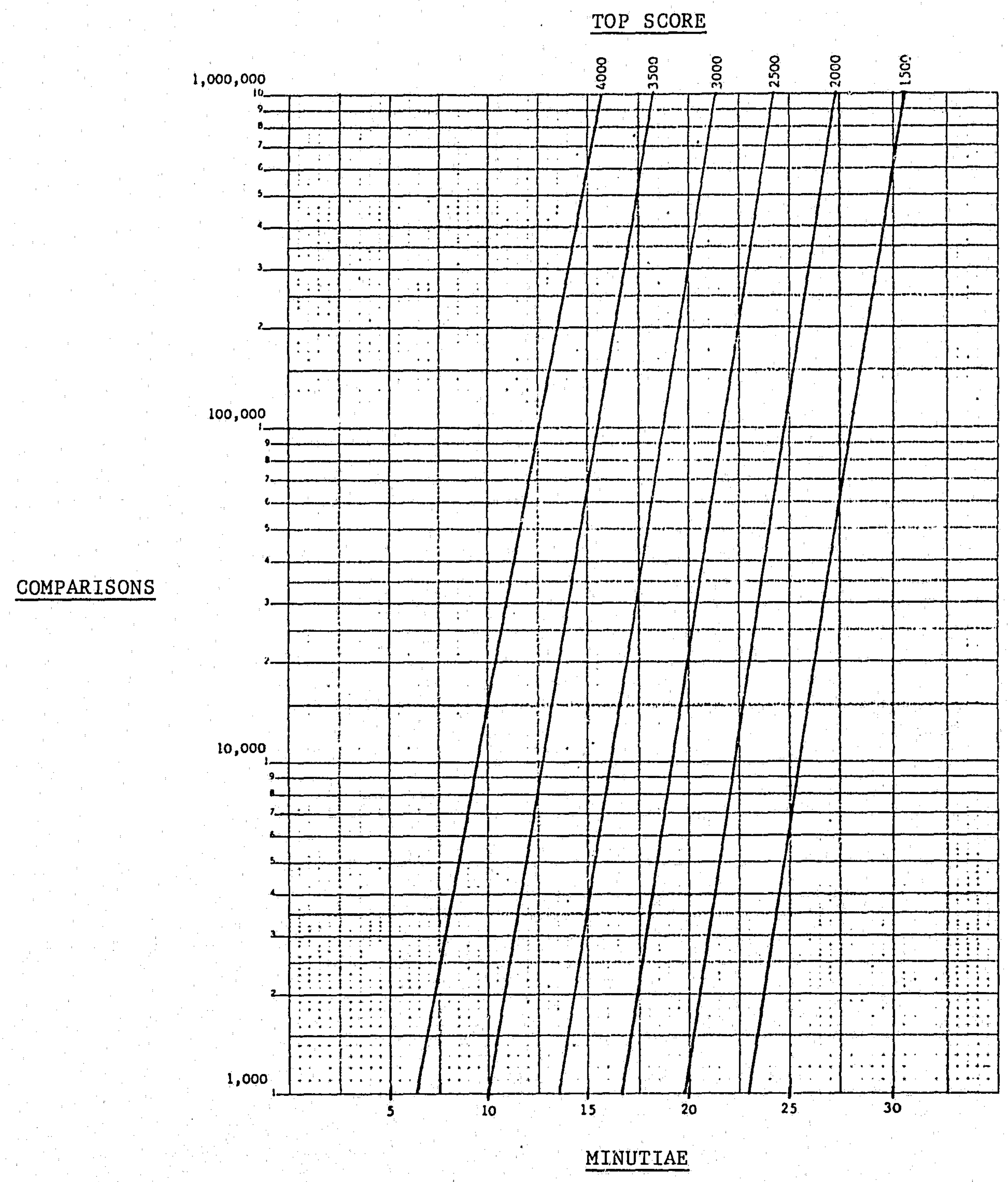
but just below the threshold (greater than 11), and 1 was predicted to be a miss. Depending on how we might judge "almost" predictions, the accuracy of the rule for the check sample is 73 percent or 91 percent.

The classification rule also gives a sense of the relative importance of the variables in obtaining a hit. For instance, a decrease in the number of comparisons from 100,000 to 10,000 has the same effect as increasing the number of minutiae encoded by two, or increasing the top score by 330.

To make the discriminant analysis helpful to system users, we have constructed a graph (Figure V-1) that shows the relations between minutiae, comparisons, and top score. The graph shows the minimum values necessary to predict a first-place hit. Such a graph may suggest to the system user whether he ought to seek to reduce the number of comparisons or encode additional minutiae, or it might suggest that a latent was unlikely to be identified and that an extensive manual verification of the suspect list would be unprofitable. The rule might also be used as a guide in deciding whether to use the slower but more accurate R40 matcher for a latent: If a print is unlikely to be identified with the R30, it is a good candidate for the R40. To use the graph, one selects two of the variables and locates the point corresponding to the values of the two variables for the latent in question. The location on the graph vis-a-vis the third variable tells what the value of the third variable must be to predict a hit.

FIGURE V-1

MAFIN DISCRIMINANT ANALYSIS:
FIRST PLACE HIT PREDICTION THRESHOLD



MAINTENANCE AND RELIABILITY

The MAFIN system is maintained under a contract with Rockwell. The agreement is renewable yearly for up to ten years at a cost of $30,000 per year in 1977 dollars. That is, the price is renegotiated each year to adjust for inflation. This amount of money is considerably less than the usual industry price for maintenance (about 1 percent of the purchase price per month). Rockwell has subcontracted with a corporate subsidiary located in Iowa for the maintenance; this unit in turn has a person in the Twin Cities area available to work on the system. The computers manufactured by Digital Equipment are maintained under a subcontract to that firm.

Statistics on time between failure and downtime (time to repair) were compiled from the MAFIN logbook for the months May through August, 1979. In order to show the actual impact of system failures on the St. Paul Police Department, several allowances were made in judging what downtime is. First, because the St. Paul Crime Lab is open only ten hours each weekday no downtime was included for off duty periods. Second, we have not counted as downtime the intervals when system operation was suspended for routine preventive maintenance or changes in system computer programs.

During the four-month sample for system reliability, the St. Paul site was out of operation 36 times for a total of 105 hours. This does not include instances when some minor function was inoperable, yet where the ordinary operations were, for the most part, unhampered. Given that there were 88 working days during the sample period, the system failed, on the average, every 2.4 days, or twice per week. (The distribution of the number of failures per day is close to that of a Poisson distribution with expectation = 0.35.)

The downtime varied from about 15 minutes to 20 hours; on the average it was 2.9 hours. The wide variation is explained primarily by whether crime lab personnel were able to get the system going again themselves or the maintenance person was called in. For a working day of ten hours the average downtime was 12 percent of available hours. (This would be 15 percent downtime on an eight-hour day, which might be closer to how the system is used.) On several days, however, the downtime was close to or equal to 100 percent. Multiple failures on the same day accounted for 14 percent of the total failures.

Undoubtedly the downtime would have been greater had not the crime lab personnel become adept at running the system. Frequently the system was returned to operation simply by shutting it down and going through the starting procedure again (rebooting).

According to the original request for proposal and proposal submitted by Rockwell, the system maintenance is to be available on request within a two-hour response time for twenty hours each day, seven days per week. However, the revised Rockwell proposal, dated March 14, 1977, states that a maintenance person will be available on an eight-hour day, five days per week shift. In a number of instances the response time exceeded that called for in the contract because the technical problem was too difficult to be handled by the local maintenance person. In general, MAFIN users here felt that Rockwell had not lived up to its agreement. This situation improved, however, as the local maintenance person became more familiar with the equipment.

More serious, it appears that there have been communication gaps between local maintenance, the Rockwell subsidiary in Iowa, and the system designers in Anaheim. Problems have recurred because they were not called to the attention of Anaheim, where engineers are capable of analyzing and correcting design weaknesses in the system. It is normal for a new system to have defects, but after a period of months these are usually isolated and corrected so that the system downtime decreases significantly; this has not yet been accomplished to the desired extent with MAFIN.

Overall, the system failures did not hamper the work of the crime lab in identifying latent prints. But much time was spent, with much annoyance, in dealing with system malfunctions.

Operating the MAFIN system also requires a variety of normal routine procedures similar to those of any other computer installation. Those procedures include the preparation of backup files and the occasional reorganization of computer files. It would be desirable to have people trained in computer work available to carry out these activities instead of the fingerprint examiners. This issue will become more critical if the system expands, or if reassignments and turnover of personnel should increase. It would be well if the MAFIN users, collectively or individually, were to consider whether their departments had other resources that might be applied to the task.

VI. MAFIN ECONOMICS

COST-EFFECTIVENESS

As important as hit rate is in judging MAFIN's effectiveness, we also need to know how much it costs to operate the equipment. By allocating the cost among the latent hits we can get an estimate of how much a hit costs, on the average. This information is critical to evaluating whether MAFIN is an efficient use of police resources and whether further expansion of the system is a good investment.

Costs for MAFIN can be computed on two bases: the total cost of the system including purchase costs and operating expenses, or the recurrent operating expenses alone. The total cost includes the federal funds that purchased the system, whereas recurrent costs are those borne by the local taxpayers. Ongoing expenses include maintenance, electricity, telephone lines, and supplies. We shall not include any personnel costs in the total because no agency added staff as a result of MAFIN's purchase; MAFIN has increased the productivity of existing staff. We will compute a cost per hit relation for both total cost and ongoing cost.

St. Paul and Minneapolis were equal purchasers of the system and we can apportion the total cost between them. We also assume that the equipment cost can be spread over ten years, as an estimated life of the equipment. (Ten years is also the duration of the maintenance agreement.) On this basis the $710,000 purchase price breaks down to an annual St. Paul or Minneapolis share of $35,540. Maintenance, in 1977

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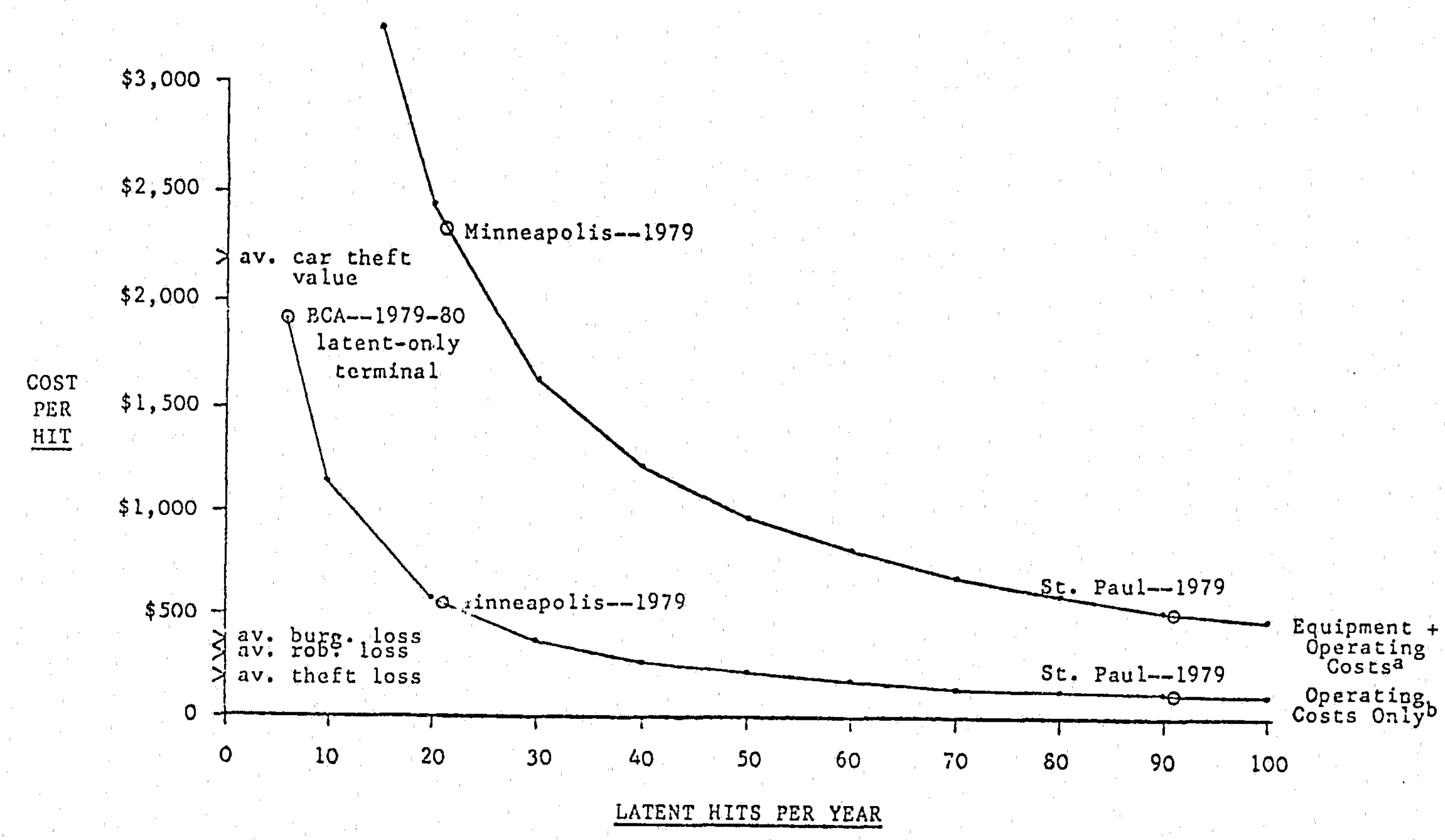
dollars, is shared among the three user agencies at $10,000 per year for each agency. Operating expenses apart from maintenance are roughly $3,600 per year, again shared by the three agencies, or $1,200 per year per agency. This gives a total of $46,740 per year for Minneapolis or St. Paul. Both cities also spent additional funds of their own for site preparation. At an estimated $20,000 for each site this adds $2,000 more to the annual agency cost. The total agency cost, in 1977 dollars, is thus $48,740 per year and the recurrent cost is $11,200 per year.

In the first year of MAFIN operation St. Paul obtained 95 latent hits. Dividing the cost by the number of hits gives $513 per hit for total cost, or $118 per hit for recurrent costs. That is, it costs the taxpayers of St. Paul only a little more than $100 for each latent identification by MAFIN in the first year of operation. As the number of crimes solved is about equal to the number of latent hits, one can conclude that MAFIN was solving crimes at the local cost of about $100 per crime.

In Figure VI-1 we plot the cost per hit for total cost and recurrent cost as a function of the number of hits per year. The graph also shows where Minneapolis and St. Paul fall on the cost curve for 1979. The BCA is shown in the recurrent cost curve because they share in those expenses. Note that the cost per hit drops sharply as the number of hits increases from zero to forty or fifty, after which there is only a small reduction in cost for each additional hit.

FIGURE VI-1

ST. PAUL AND MINNEAPOLIS MAFIN COSTS PER LATENT HIT
(1977 constant dollars)



[a]Includes LEAA, state, and local share of initial capital expense.

[b]Reflects cost to local agency for continued system operation.

Because good data on what it costs to solve crimes does not exist, it is difficult to evaluate whether MAFIN is more or less effective than other police procedures at solving crimes. We can, however, compare MAFIN costs to the average losses in crimes or to the costs of latent identification using traditional manual procedures.

The average losses in theft, robberies, and burglaries range from about $200 to $480. A MAFIN site obtaining thirty or forty latent hits per year will be solving crimes at about this same range of cost to local taxpayers. Given the good potential for recovering stolen goods after a MAFIN identification, this cost comparison seems favorable to MAFIN.

The budget of the St. Paul Crime Lab for fingerprint work, including half of the director's salary and other salary and expenses, is about $110,000. In 1979, the Lab made 246 manual identifications, which gives a cost per manual identification of about $450, excluding any MAFIN costs from consideration. Thus, the marginal cost to the Lab for a MAFIN hit, assuming the fixed budget already existed for manual identification work, is about one-fourth of the cost of a manual identification. By this comparison, as well, MAFIN is a favorable investment of resources and a beneficial factor in Crime Lab productivity.

The cost-effectiveness of the existing system shows also the benefit of the low initial purchase price in comparison to current equipment costs. If new equipment is added to the system, it will be more costly and require higher levels of performance to maintain the same cost-effectiveness as is presently shown. In considering expenditures, the reader is also advised to adjust the maintenance cost for inflation since 1977.

If the MAFIN site in St. Paul were operated at the capacity shown in the peak months of 1979, marginal local costs would be only $41 per hit. It is hard to judge, however, what additional police department costs might be necessary to keep the flow of latents at the peak level.

In these discussions no mention has been made of the other use of the MAFIN system, namely the identification of persons from fingerprint cards. Depending upon what value one assigns to this activity--and greater use could be made of this capability--the costs of latent identification would be correspondingly reduced.

COSTS OF FUTURE EXPANSION

If one accepts the view that the MAFIN system ought to provide the same level of service to all citizens of the state, then one must consider future improvements to the system. Chief among these would be the purchase of a 250S Read/Edit terminal and Print processor by the state for the Bureau of Criminal Apprehension (BCA). Additional possibilities would include supplying remote terminals to major law enforcement agencies outside the Twin Cities area or at the Hennepin County Sheriff's Office.

The upgrading of BCA equipment to the level of Minneapolis and St. Paul entails costs for equipment and maintenance. Because new equipment is not covered under the existing maintenance contract, the price of maintenance will increase significantly for any new equipment. Inflation is having a significant impact on all equipment purchases, so that without a proposal in hand a fixed price is not available. Never-the less, the most recent estimate for a 250S subsystem is $530,000. The maintenance for this is $75,600 per year. Other operating costs add about $1,500. In addition, the BCA must still pay its third of the recurrent expenses of the existing system, which in current dollars is about $1,500 per year. Total recurrent costs for an upgraded BCA site are, therefore, $92,100 per year. If we spread the initial equipment cost over ten years, this brings the total annual cost to $155,000. As before, we can plot a cost per latent hit curve for total and recurrent expenditures. This is shown in Figure VI-2. This does not include potential benefits or savings in BCA card identification, which, for example, would be achieved through improved identification services and retirement of the microfilm system currently in use for identification.

The cost of a latent-only terminal placed at an outstate site is about $95,000 plus $11,400 for annual maintenance. In Figure VI-3 we again graph the cost per latent hit relationships.

At first glance, a comparison of the cost curves for the BCA and for potential outstate terminals appears highly favorable to the latter. And, indeed, if the placing of a latent terminal at an outstate site were to generate enough new latent evidence collection to yield 40 or 50 hits per year, it would be as cost-effective as the current sites in Minneapolis and St. Paul. But two factors mitigate the seeming advantage of outstate sites vis-a-vis the BCA. First, the BCA must maintain the card files for the outstate agencies, and to do this may require the BCA having a 250S subsystem. Furthermore, an agency's existing card file might have to be added to the system file. The BCA now has a large backlog of unentered cards which will increase even more if the volume of fingerprint work increases in Minneapolis, making difficult the BCA's access to that 250S terminal for card entry. Second, it is questionable whether outstate agencies will increase their latent work

FIGURE VI-2

ESTIMATED COST PER LATENT HIT FOR A BCA 250S
TERMINAL AND PRINT PROCESSOR

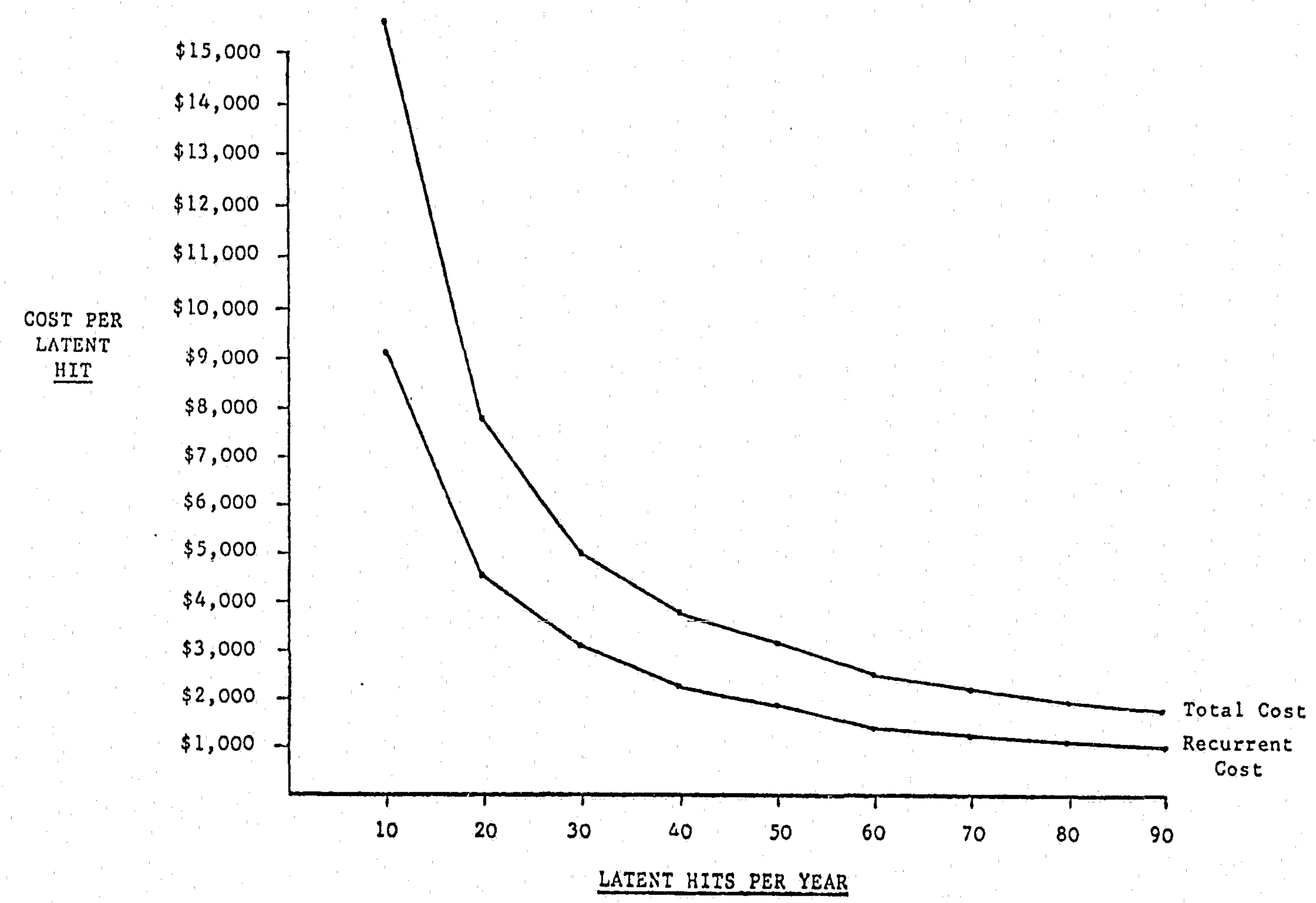
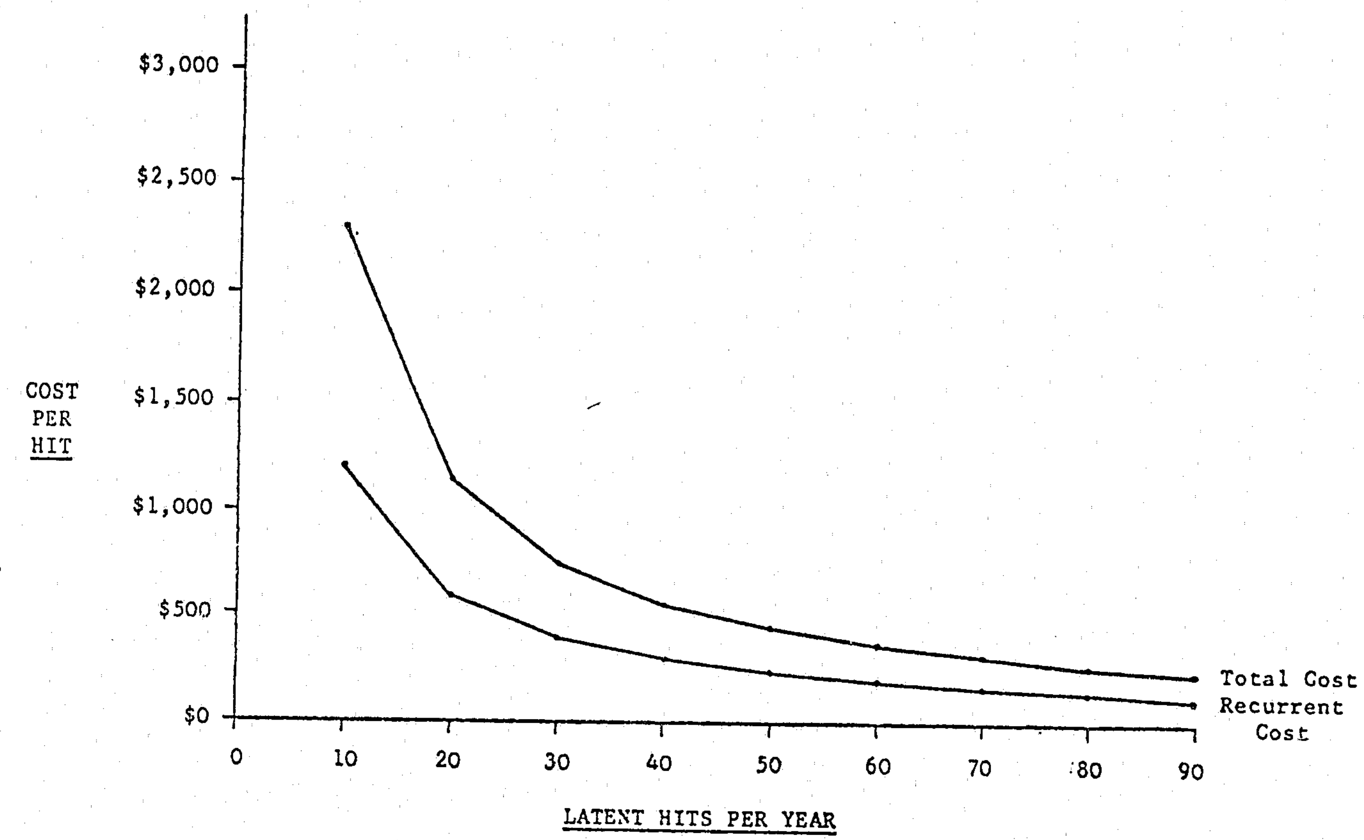


FIGURE VI-3

ESTIMATED COST PER HIT WITH MODEL 30 LATENT TERMINAL



significantly. To judge from the volume of latent work now being processed at the BCA from outstate agencies, the quantity of latents does not support a remote terminal.

This is not to say that the potential does not exist for expanded latent collection throughout Minnesota. In 1979, Minnesota had a total of 45,000 reported burglaries. The number of burglaries outside the metropolitan area was over 15,000, which is more than double the number in St. Paul. Whether the MAFIN system or future additions are cost-effective will depend mainly on increasing the commitment to thorough physical evidence processing at crime scenes throughout Minnesota. But how this might be accomplished is an open question. Is it better approached through improved local level service (as local MAFIN terminals) or through training and service by the BCA at the state level?

VII. ISSUES AND RECOMMENDATIONS

The MAFIN system has opened new possibilities for law enforcement in Minnesota. It can solve crimes where a fingerprint is the only evidence: crimes that almost never were solved in the past. And MAFIN has expanded the capability for identification of persons much beyond what has been practical to this time. So revolutionary are these newly created possibilities that they give the impression that law enforcement is a step behind the times in evidence collection, and where there were true shortcomings before, they have become more apparent.

If we think about how MAFIN best serves the state, it may be in the stimulus and challenge it gives to improve evidence collection and identification. One might look at the MAFIN statistics for outstate Minnesota, or for the suburbs of Minneapolis and St. Paul, for example, and conclude that there is insufficient demand to support the system in these areas. Yet we know that the potential exists for latent fingerprint collection at thousands of crime scenes where it is not now being done. It is only with MAFIN that the incentive has been brought about to do the work.

As we look to future expansion of MAFIN we also must ask whether the need is there. But, again, one might respond that the need will never make itself known without the capability to do something about it. The obstacles to bringing law enforcement in Minnesota up to the level of MAFIN's capacity are not technical but involve organization, training, cooperation among agencies, and education as to what the potential is. Measures are already being taken by the MAFIN users to improve system usage; more needs to be done.

For the future, several problems need attention. The foremost is the financing of the system. With the elimination of most federal funds for criminal justice, new sources of money must be tapped. Here we see a need for the state legislature to make a commitment to MAFIN as a statewide system. Without legislative action the level of cooperation between the state and Minneapolis and St. Paul will certainly diminish, and the system will likely become a service available only to residents of Hennepin and Ramsey counties. Specifically, financial investment is needed in the operating and maintenance expenses, in the upgrading of the equipment of the Bureau of Criminal Apprehension, and in improvement to the central computer programs. Other possibilities include the addition of latent-only terminals at selected sites around the state and an expanded disc file capacity. Given how the system operates, a direct appropriation of funds from the state legislature to St. Paul for operating and improving the system would be the most suitable method for increasing state participation in MAFIN, after the purchase of a 250S terminal by the BCA for the processing of the state's fingerprint cards.

The state may also adopt policies or modify legislation to increase the effectiveness of the system. Current legislation on fingerprint identification makes these stipulations, which we paraphase:

1. The BCA is to install a system of identification which includes the use of fingerprints and obtain fingerprints for the record of those persons convicted of a felony or gross misdemeanor (299C.09).

2. It is made the duty of sheriffs and police to take immediately fingerprints (and other identification data) of a person arrested for a felony or gross misdemeanor and of a juvenile commiting a felony (and of certain others) and within 24 hours to forward such fingerprint records and other identification data to the BCA (299C.10).

3. Fingerprints and other identification, as required, must be furnished to the BCA by sheriffs and police for persons convicted of a felony or gross misdemeanor; if the arrested person is not convicted, the fingerprint record must be returned (purged) upon demand, unless the person has a prior felony conviction within the ten preceding years (299C.11).

4. "The bureau shall cooperate and exchange information with other organizations for criminal identification, within and without the state, for the purpose of developing, improving, and carrying on an efficient system for the identification and apprehension of criminals" (299C.15).

From the perspective of operating and improving the MAFIN system, the law offers several possibilities, although changes in the law might clarify its intent. Experience with MAFIN shows the value of having fingerprint records of juveniles who have committed crimes. Although the law seems to require the fingerprinting (and identification) of juveniles arrested for felonies, this is not a routine practice in Minnesota. The primary reason for this seems to be that the BCA does not accept or retain juvenile fingerprint records. This policy may reflect the difficulty the BCA would have in trying to obtain disposition records on juvenile delinquency cases.

It is feasible to maintain an identification file on juveniles that does not contain records of delinquent behavior, if it is the recordkeeping that is the drawback to implementation. An identification file might, for instance, have only references to the local agency (or agencies) where the juvenile's record is kept. However, we can also argue for the keeping of juvenile delinquency records at the state level. The newly enacted sentencing guidelines, and other changes in the law on the referencing of juveniles to adult court, increase the need for accurate identification and accurate record keeping of juvenile delinquents. Under the sentencing guidelines a person's juvenile court records may be used to a limited extent in determining an adult court sentence. Yet it is difficult to see how this can be fairly applied when, at present, great variations abound in the keeping of juvenile records in this state, and when there is no common file.

Similar considerations might be applied to adults convicted of misdemeanors. Although sentencing guidelines will take misdemeanor records into account, no central file exists for these records.

Any increase in the state's record keeping will, of course, have an impact on the MAFIN system. The disc drive capacity would have to be increased, and the BCA would need a 250S terminal and print processor. The BCA equipment might, however, alleviate the need for any great increase in personnel that ordinarily would accompnay expanded record keeping.

In the statutes cited, the mandate for the state to cooperate with local agencies in developing an effective identification system could not show greater foresight, so apt it is to the MAFIN system. What is needed now is the fulfillment of this mandate through a state commitment of money and planning, with the goal of exploiting the capabilities of statewide automated identification.

GLOSSARY

CLASSIFICATION: A method for organizing and filing fingerprint cards on the basis of the gross pattern of the fingerprints; does not identify prints.

CLASSIFY: To determine where in a card file a fingerprint card ought to be filed.

CLEARANCE: The solving of a crime, as determined by a police investigator (not a court).

DISC DRIVE: A device for storing computer data on rotating magnetic discs.

FINGERPRINT CARD: The inked impression of the ten fingers of a person made on a standard card upon the person's arrest; used for identification and criminal record keeping.

FILE STRUCTURE: The organization of fingerprint data on the computer's disc memories; critical to speed of system at matching prints.

HIT: An identification of a criminal from a latent fingerprint using the MAFIN computer.

HIT RATE: The percentage of identifications made among those latents entered into the computer.

LATENT-ORIENTED SYSTEM: An automated fingerprint identification system that can identify latent prints, not just cards alone, and designed to optimize latent work over card work.

LATENT PRINT: The impression of a fingerprint recovered at the scene of a crime or on physical evidence involved in a crime.

MINUTIA (plural, minutiae): A small identifying characteristic of a fingerprint (or palm, or sole, etc.) where two ridges come together or where a ridge ends; the arrangement of these characteristics is unique to each finger of every person and therefore can be used for positive identification.

MINUTIAE-BASED SYSTEM: An automated fingerprint identification system that uses minutia arrangements as the basis for identifying fingerprints.

MATCHER: The electronic device that compares the minutiae arrangement of a fingerprint from a crime or from a fingerprint card against the minutia arrangements of fingerprints in the MAFIN file.

MATCH RATE: The average number of comparisons a matcher can make in an interval of time.

MICROFICHE: A card that contains many photographs (negatives) of fingerprint cards, much reduced in size.

PRINT PROCESSOR: Processes cards entered into MAFIN through a Read/Edit terminal; automatically locates minutiae and sends this information to the search processor.

READ/EDIT TERMINAL (250S): Capable of entering fingerprint cards or latents and other descriptive information into the MAFIN system; accepts instructions from operator for MAFIN operation.

RESPONDENT LIST: The list of fingerprints output from the computer that are most like the print entered for identification, ranked in order of most likely suspect, with identification number.

SEARCH AND MATCH PROCESSOR: Controls the matchers and the storage of fingerprint information on the disc files.

VERIFICATION: A fingerprint exminer must visually confirm that tentative identifications (respondents) by the computer are indeed correct; the examiner compares the minutiae pattern of a latent print with that of a print on the suspect's fingerprint card.

END