- Hughes, W.E., Reinfurt, D., Yohanan, D., Rouchon, M., and McGee, H.W. (1993). New and Emerging Technologies for Improved Accident Data Collection. McLean, VA: Federal Highway Administration.

Publication No. FHWA-RD-92-097
March 1993

New and Emerging Technologies for Improved Accident Data Collection

U.S. Department of Transportation
Federal Highway Administration

Research and Development
Turner-Fairbank Highway Research Center
6300 Georgetown Pike
McLean, Virginia 22101-2296

FOREWORD

This report presents information related to an investigation of the potential application of new and emerging technologies to improve accident data collection and the quality of accident data. The focus of the study was on technologies that are currently available and could be implemented by State and local police agencies responsible for accident reporting and records systems. This report will be of interest to administrators and managers of accident records sections, highway safety analysts, police officers and supervisory personnel, and others involved in the collection and processing of accident reports data.

Lyle Saxton
Director, Office of Safety and Traffic Operations Research and Development

NOTICE

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipients Catalog No.
FHWA-RD-92-097		

4. Title and Subtitle	5. Report Date
NEW AND EMERGING TECHNOLOGIES FOR IMPROVING ACCIDENT DATA COLLECTION	March 1993
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No.
Warren E. Hughes, Donald Reinfurt, David Yohanan, Margaret Rouchon, and Hugh W. McGee	
9. Performing Organization Name and Address	10. Work Unit No. (TRAIS) NCP No. 3A3A2112
Bellomo-McGee, Inc. 8330 Boone Blvd., Suite 700 Vienna, VA 22182	11. Contract or Grant No. DTFH61-91-C-00043
12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered Final Report July 1991- October 1992
Office of Safety and Traffic Operations R&D Federal Highway Administration 6300 Georgetown Pike McLean, VA 22101-2296	14. Sponsoring Agency

15. Supplementary Notes
Contracting Officer's Technical Representative (COTR) - Paul A. Pisano, HSR-30
Farradyne Systems, Inc. and the University of North Carolina, Highway Safety Research Center were subcontractors.

16. Abstract

This study entailed the identification and examination of technologies and a review of the current processes related to the collection and management of motor vehicle traffic accident data. The study identified those technologies that are most promising in terms of improving the quality, accuracy, completeness, and timeliness of the accident data and/or reducing the demands on police officers, accident investigators, data coders, and data entry personnel. The technologies that were examined in detail included the following: form readers/optical scanners, laptop and notebook computers, pen-based portable computers, identification technologies including magnetic stripe, bar codes, "smart" cards, Automatic Vehicle Identification (AVI), the Global Positioning System (GPS), and location technologies. Detailed reviews of the processes, procedures, reporting requirements, and management of information related to traffic accident data were conducted for a sample of nine States. Interviews were conducted with people involved at all levels of the accident data collection and analysis process, including police officers, data coders, key-entry personnel, safety analysts, State and local traffic engineers, and computer systems/information management personnel. In addition, the applications of various technologies to the accident data collection and analysis process or a related process were identified and researched.

17. Key Words	18. Distribution Statement
Technology, accident data collection, accident reporting, accident records systems, notebook computers, pen-based computers, laptop computers, Global Positioning System (GPS).	No Restrictions. This document is available to the public through the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161

19. Security Classif.(of this report)	20. Security Classif.(of this page)	21. No of Pages	22. Price
Unclassified	Unclassified	115	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yards	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	ml
gal	gallons	3.785	liters	l
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5(F-32)/9 or (F-32)/1.8	Celcius temperature	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	l
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
psi	poundforce per square inch	6.89	kilopascals	kPa

NOTE: Volumes greater than 1000 l shall be shown in m^3.

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	ac
ha	hectares	2.47	acres	mi^2
km^2	square kilometers	0.386	square miles	
		VOLUME		
ml	milliliters	0.034	fluid ounces	fl oz
l	liters	0.264	gallons	gal
m^3	cubic meters	35.71	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg	megagrams	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	Celcius temperature	1.8C + 32	Fahrenheit temperature	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	psi

* SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.

(Revised August 1992)

TABLE OF CONTENTS

Chapter		Page
1.	INTRODUCTION	1
	OBJECTIVES	1
	BACKGROUND	2
	ORGANIZATION OF THIS REPORT	2
2.	THE ACCIDENT DATA COLLECTION PROCESS AND THE POTENTIAL ROLE OF TECHNOLOGY	3
	OVERVIEW OF THE CURRENT ACCIDENT DATA COLLECTION PROCESS	3
	SUMMARY OF KEY DEFICIENCIES	7
	Administrative/Staffing Problems	7
	Timeliness	8
	Legibility of Reports	8
	Incomplete Reports/Missing Data	8
	Errors/Inconsistencies	9
	Data Problems	9
	TECHNOLOGY TO IMPROVE THE ACCIDENT DATA COLLECTION PROCESS	12
3.	DATA PROCESSING TECHNOLOGIES FOR AUTOMATING ACCIDENT DATA REDUCTION	15
	OPTICAL SCANNERS TO SCAN AND STORE ACCIDENT REPORTS	15
	Application of Optical Scanners in Virginia and Anaheim	15
	Anticipated Benefits	18
	Limitations/Disadvantages	18
	FORM READER SYSTEMS TO EXTRACT DATA FROM REFORMATTED ACCIDENT REPORT FORMS	19
	Application of Form Readers in Michigan	19
	Implementation Steps	22
	Equipment	25
	Implementation Costs	27
	Anticipated Benefits	28
	Limitations/Disadvantages	29
4.	COMPUTER TECHNOLOGY FOR AUTOMATING THE COLLECTION OF DATA AT THE ACCIDENT SCENE	33

TABLE OF CONTENTS (Continued)

Chapter Page

PORTABLE COMPUTERS 33

Laptop Computers 33
Notebook Computers 34
Pen-Based Computers 34
Palmtop Computers 36

APPLICATION OF PORTABLE COMPUTERS TO THE ACCIDENT DATA COLLECTION PROCESS 37

Existing Applications by State and Local Police Agencies 37
Implementation Scenarios 46
Operating Systems 48
Implementation Costs 48
Software Requirements 49
Implementation Steps 50
Anticipated Benefits 50
Limitations/Disadvantages 51

RELATIVE COMPARISON OF COMPUTER TECHNOLOGY FOR ACCIDENT DATA COLLECTION 52

5. TECHNOLOGIES FOR AUTOMATING THE COLLECTION OF DRIVER AND VEHICLE IDENTIFICATION DATA 55

IDENTIFICATION TECHNOLOGIES 55

Magnetic Stripe Technologies 55
Bar Coding Technologies 56
"Smart" Cards with Radio Frequency Chips 57

RELATED APPLICATIONS OF IDENTIFICATION TECHNOLOGIES 57
RELATIVE COMPARISON OF IDENTIFICATION TECHNOLOGIES 63
APPLICATION OF PERIPHERAL EQUIPMENT FOR IDENTIFICATION TECHNOLOGIES 63

Implementation Schemes 64
Equipment 64
Anticipated Benefits 67
Limitations/Disadvantages 68

6. TECHNOLOGIES FOR AUTOMATING THE COLLECTION OF LOCATION DATA 71

TABLE OF CONTENTS (Continued)

Chapter | Page

LOCATION TECHNOLOGIES 71

Loran-C 72
Map Matching/Dead Reckoning Systems 72
Cellular Phones 74
Global Positioning System 76

RELATIVE COMPARISON OF LOCATION TECHNOLOGIES 78
SAFETY-RELATED GPS APPLICATIONS 79
APPLICATION OF GPS TECHNOLOGY TO ACCIDENT DATA COLLECTION 80

Equipment Options 81
Implementation Costs 82
Training 82
Anticipated Benefits 83
Limitations/Disadvantages 83

7. PROMISING EMERGING TECHNOLOGIES FOR THE FUTURE 85

OPTICAL CHARACTER RECOGNITION 85
VOICE INPUT 86
SMART CARDS WITH DRIVER RECORDS 86
AUTOMATIC VEHICLE MONITORING AND TRACKING SYSTEMS 87
DIGITAL CAMERAS 87
DISTANCE MEASUREMENT DEVICES FOR ACCIDENT RECONSTRUCTIONISTS 88
ADVANCED INVEHICLE NAVIGATION SYSTEMS 89
BLACK BOX RECORDERS FOR AUTOMOBILES 89
HEADS-UP DISPLAY 91
IMPROVED AUTOMATED INCIDENT DETECTION SYSTEMS 92

8. SUMMARY 93

DEFICIENCIES WITH THE CURRENT ACCIDENT DATA COLLECTION PROCESS 93
POTENTIALLY APPLICABLE TECHNOLOGIES 94
REVISED ACCIDENT REPORT FORMS AND FORM READERS 95
PORTABLE COMPUTERS 96
LOCATION TECHNOLOGIES 98
IDENTIFICATION TECHNOLOGIES 100
FORM READERS VS. COMPUTERS 102
MODEL INTEGRATED ACCIDENT DATA COLLECTION SYSTEMS 103
EMERGING TECHNOLOGIES FOR TOMORROW 105

REFERENCES 107

LIST OF FIGURES

Figure		Page
1.	Accident data collection and analysis process	4
2.	Illustration of possible error associated with the accident location as reported by the police	10
3.	An optical scanner used by VDOT	16
4.	A computer-generated hard copy of a scanned accident report from VDOT's system	17
5.	An optical disk as an alternative storage media	18
6.	Michigan's old accident report form	20
7.	Front side of Michigan's revised accident report form	23
8.	Back side of Michigan's revised accident report form	24
9.	A pen-based clipboard computer	35
10.	A RAM card and a smaller version of a pen-based clipboard computer	36
11.	The Tandy Model 102 computer used by the St. Petersburg Police Department	38
12.	Clearwater Police Department's mounting harness with and without the Toshiba computer	39
13.	Santa Cruz Police Department's motorcycle-mounted laptop computer system	42
14.	A Johnson mobile data terminal on the motorcycle to interface with a Motorola radio for digital two-way communication link	42
15.	San Jose Police Department's Motorola mobile data terminal	45
16.	Illustration of a pen-based clipboard computer with external keyboard in a police vehicle	46

LIST OF FIGURES (Continued)

Figure		Page
17.	Front of a California driver's license	58
18.	Back of a California driver's license	58
19.	Radix Corporation's Automatic Citation Device and printer	59
20.	Illustration of the magnetic stripe reader with a California driver's license	59
21.	Process for using the Automated Citation Device to issue citations	60
22.	Computer-generated citation	61
23.	Process for remote access to California DMV's driver record files	62
24.	Heads-up display	91

LIST OF TABLES

Table		Page
1.	Estimated time from accident to processing at data center	8
2.	Price comparisons of form reader systems with optical character recognition	28
3.	Length of bar codes for common symbology	57
4.	Implementation scenarios for portable computers	97

CHAPTER 1. INTRODUCTION

The Federal Highway Administration (FHWA) has been and continues to be concerned with the quality of motor vehicle traffic accident data that becomes available to the highway safety analyst/traffic engineer at the State or local level. The FHWA is concerned that the quality, completeness, and timeliness of these data may not be adequate to promote the systematic analysis of motor vehicle traffic accidents, the identification of locations with unusually high accident occurrence, the evaluation of accident reduction programs, and the continued surveillance of the highway system. Accident data provide feedback on the performance of the entire driver-vehicle-roadway-environment system. Since a motor vehicle traffic accident represents a failure of one or more elements of the system, accident data provide the critical information necessary to apply appropriate corrective actions.

In addition to the safety aspects of accident data collection, the FHWA is equally concerned with the adverse impact that motor vehicle traffic accidents have on traffic flow and air quality, especially on urban freeways and arterials. The Intermodal Surface Transportation Efficiency Act (ISTEA) authorized $6 billion over 6 years for the establishment of a "Congestion Mitigation and Air Quality Improvement Program." The Act also sets forth the requirement that the FHWA issue regulations to develop and implement management systems for highway safety and traffic congestion. It has been estimated that 60 to 65 percent of the delay experienced in an urban area is attributable to nonrecurring incidents that include traffic accidents. Accidents in which lanes are temporarily blocked contribute to this delay. Consequently, the FHWA is interested in improving the accident data collection process because it plays a key role in freeway incident management. The expedient collection of accident data may be a potential mitigation measure to reduce nonrecurrent congestion.

OBJECTIVES

The objectives of this study were to:

- Examine the accident data collection process at the State and local level and identify areas where new technologies may be applied.
- Examine new and emerging technologies that could be applied to the accident data collection process.
- Examine the potential benefits that would be accrued by State and local agencies once the technologies are implemented.
- Generate specific recommendations for a State or local agency that identify ways in which these technologies could be easily implemented.

BACKGROUND

In the early 1970's, the U.S. Department of Transportation established standards for a national highway safety program. The authority for the standards and the Highway Safety Program is contained in chapter 4 of title 23, U.S.C. (hereinafter referred to as the Highway Safety Act of 1966). Two standards specifically apply to accident reporting and the identification of accident locations. The FHWA retained authority for the administration of standard no. 9, Identification and Surveillance of Accident Locations and for three other standards. The purpose of Highway Safety Program standard no. 9 is:

> To identify specific locations or sections of streets and highways which have high or potentially high accident experience, as a basis for establishing priorities for improvement, selective enforcement, or other operational practices that will eliminate or reduce the hazards at the location so identified.[1]

The Highway Traffic Safety Act of 1970 established the National Highway Traffic Safety Administration (NHTSA) and assigned to it the responsibility of administering the safety program standards pertaining to the automobile and the driver, including standard no. 18, Accident Investigation and Reporting. The purpose of Highway Safety Program standard no. 18 is:

> To establish a uniform, comprehensive motor vehicle traffic accident investigation program for gathering information -- who, what, when, where, why, and how -- on motor vehicle traffic accidents and associated deaths, injuries, and property damage, and entering the information into the traffic records system for use in planning, evaluation, and furthering highway safety program goals.[2]

ORGANIZATION OF THIS REPORT

Chapter 2 presents an overview of the current accident data collection and reduction process, describes the major deficiencies of the current processes, and indicates how new and emerging technologies can improve the deficiencies. Chapter 3 describes technologies to automate the reduction of accident data. In chapter 4, computer technologies that can be used by police at the scene of the accident to automate the preparation of accident reports are described. Chapter 5 contains a discussion of technologies for the collection of driver and vehicle information. Location technologies are discussed in chapter 6. Chapter 7 identifies and describes additional emerging technologies that potentially can be applied in the future to the accident data collection and reduction process. Finally, a summary is presented in chapter 8.

CHAPTER 2. THE ACCIDENT DATA COLLECTION PROCESS AND THE POTENTIAL ROLE OF TECHNOLOGY

Before identifying and describing the technologies that could be applied to the accident data collection process, it is beneficial to briefly describe the current processes and identify the major deficiencies.

OVERVIEW OF THE CURRENT ACCIDENT DATA COLLECTION PROCESS

The overall process for the collection, reduction, management, and analysis of accident data can be stratified into six distinct processes, which are shown in figure 1. The notification and emergency vehicle response process relates to the initial period immediately after the accident occurs until the time the investigating police officer arrives at the scene. The scope of this study was focused on the activities that begin after the officer arrives. Hence, the notification and response process is not addressed in this report. The remaining processes are described in more detail in the following paragraphs.

Upon arrival, the police officer may render emergency medical assistance (if the police officer responding to the report arrives at the scene before fire department or emergency medical personnel), stabilize the scene, and re-establish traffic flow. With respect to accident reporting, the officer needs to determine the chain of events (e.g., what happened) and decide whether a citation(s) should be issued or specific drivers charged. The officer will also initiate the preparation of a report, if warranted. In most States, the reporting threshold is legislatively mandated. For all States, if a personal injury or fatality has resulted from the accident, then the police must complete an accident report form. In many States, a minimum property damage value of $200 to $1,000 has also been established as a reporting threshold. Some States apply the threshold only to personal injury accidents or accidents in which one or more vehicles must be towed from the scene (e.g., tow-away accidents).

With respect to the accident report form, each State has developed their own unique form. There is no national standard format for an accident report and the Federal Government has not mandated that one specific form be used for reporting motor vehicle traffic accidents. In most States, the State and all local police agencies are required by law to use one common standardized police accident report form that has been developed for that State. There are, however, several notable exceptions, such as California where the cities of Los Angeles, San Jose, and San Diego use forms that differ from the California Highway Patrol's form.

Generally, city and local municipal police officers complete an accident report form for accidents that occur within their jurisdictional limits. Accidents that occur outside these city limits on State highways are usually investigated and reported by State police. In some States, the State police will assist and prepare reports for accidents on interstate and other State highways within a city or municipality. In some States, some sheriff's departments will investigate and report on accidents on roads within their county or jurisdiction. In most cases, the accident report form is handwritten in the field by the police officer. Some officers make notes at the scene and then return to the office to complete the form. There are a few officers and agencies that type their reports at headquarters. Estimates were that generally no more than 5 to 15 percent of the

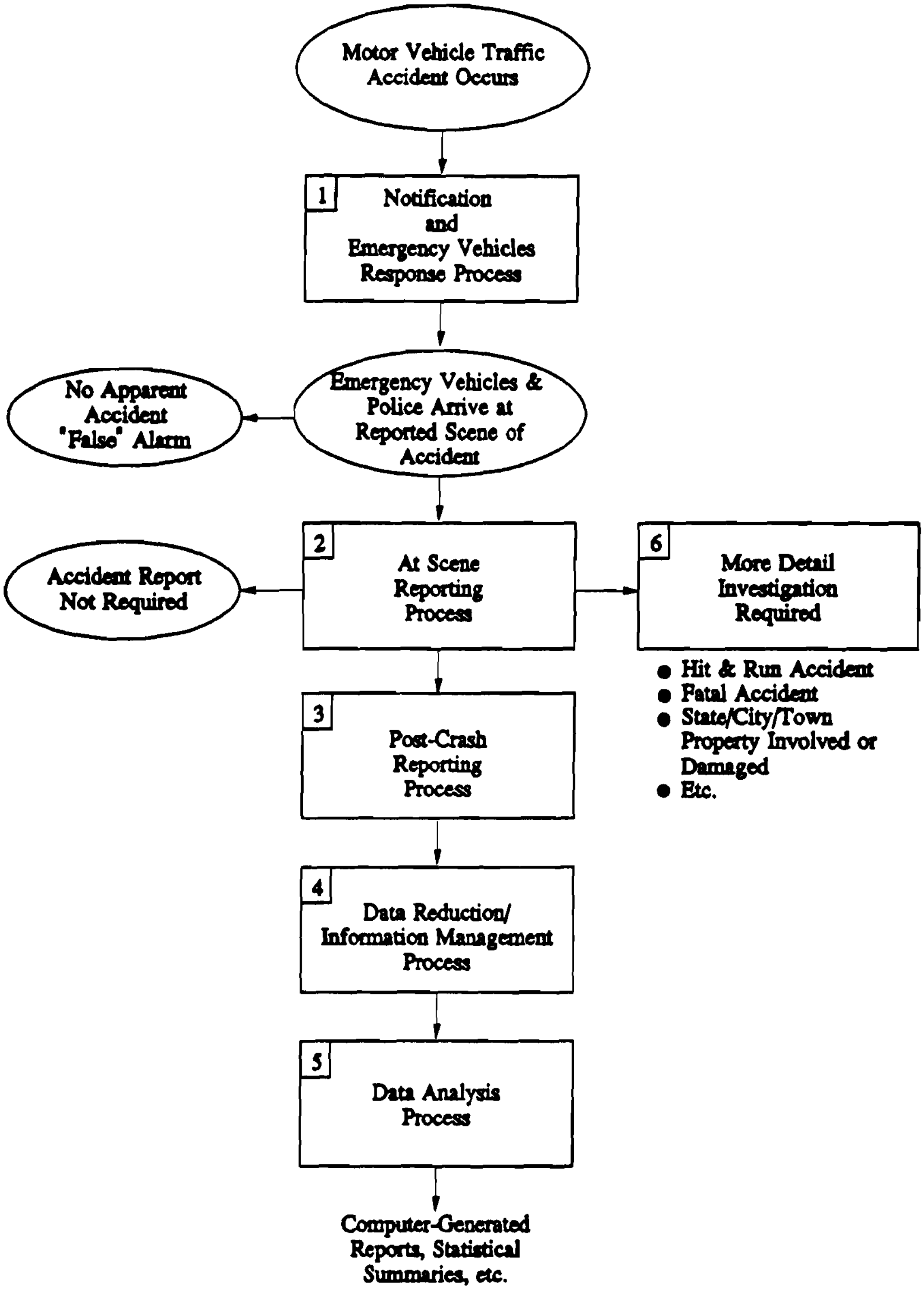


Figure 1. Accident data collection and analysis process.

police accident reports that come into the data center for a State are actually typed, and very few are computer generated.

There are several different practices related to recording location information on the accident report form. In all States, the police officer is instructed to provide location information (e.g., city/county/town name, name of road, route number, etc.). Most States require the officer to fill in the distance and direction to a cross street or landmark. Several States have established link-node location reference systems and require police officers to fill in a node number and the distance and direction to (or from) that node on the accident report. A few States require the police officers to determine the appropriate milepoint on the State highway where the accident occurred.

In many States, drivers are required to complete a form if they are involved in an accident even if a police officer prepared an accident report form for the accident. In a few States, drivers are required to complete an operator's report of an accident only if the police do not prepare a report because the reporting threshold is not exceeded (e.g., no personal injuries). Driver or operator reports are generally administered through the departments of motor vehicles and are required for financial responsibility laws.

Many local police agencies will prepare or accept "counter reports." A driver can walk into a police station and ask that an accident report be filed. However, "counter" reports filed by a driver are generally not entered into the State data base record system. In some cities, police clerks behind the counter at police stations will complete reports filed by driver. In some cities, the form is provided to the driver who then fills it out.

For some accidents, additional investigative efforts may be needed. These include fatal accidents, hit-and-run accidents, accidents involving damage to State/city/county/town property, accidents involving a State/city/county/town vehicle even if it is not apparently damaged, driving while intoxicated (DWI) accidents, and serious injury accidents, among others. Most large law enforcement agencies have established accident reconstruction teams that include personnel trained in the detailed investigation of motor vehicle traffic accidents. For selected accidents, the accident reconstruction team is called in to conduct a more detailed investigation of the scene of the accident.

Many times a police officer cannot complete the accident report form at the scene of the accident due to the need to get congested traffic moving again, additional high priority calls, weather, or other factors. Frequently, the officer completes the report at another location in the field or at the police station later during the shift or even during the next shift. In fact, based on several informal interviews, police officers do not typically complete the entire report at the scene of the accident, especially on heavily traveled roads subject to congestion. Rather, they record the key data from the driver licenses and vehicle registrations and other information at the scene and then fill in other fields on the accident report form later. Several States have implemented accident investigation sites that are areas designated with signs and markings often located on off ramps from freeways. Drivers involved in minor damage accidents are instructed to drive to these sites and, if warranted, the police officer will complete an accident report form.

After the investigating police officer completes and signs the accident report, it typically goes to a supervisor, such as the desk sergeant, for approval. Typically, these supervisors are much more attentive to and critical of reports completed by rookie and less experienced officers. After the supervisor completes the quality control check and approves the report, the form is typically sent to the records division of the police department who then sends the original reports or copies to the central State agency, located in the State capital, charged with responsibility for accident data. There are a variety of State agencies that have the responsibility for compiling data from accident report forms and analyzing these data. In some States, the central State agency is the State police. In other States, the Department of Highway Safety and Motor Vehicles, the Department of Transportation (DOT), the Highway Department, the Department of Motor Vehicles (DMV), or the Division of Motor Vehicles is the designated State agency. For example, the California Highway Patrol maintains the data in California, whereas the DOT is the responsible agency in Michigan and Pennsylvania. In New York, the DMV maintains the data.

In most States, there is initial screening at the State data center for legibility as well as for certain key items to be completed such as date, time of accident, location, and other items. In most instances, the reports are returned to the local jurisdictions if this key information is not provided. Depending on the State's practices and procedures, coders may review other information on the form and annotate additional codes.

In many States, data processing personnel at the Department of Transportation or the central State data center subsequently codify the location based on the name of the road, route number, and the distance and direction to an intersecting crossroad or landmark (e.g., a mile marker sign, bridge, etc.) recorded on the report form. In several States, software is used to match the route name and number, cross street name and number, and location information that is key-entered to the existing location reference system. In a few States, the data processing personnel do not code location data. Rather, the police officer records the distance to (or from), direction to (or from), and the number of the nearest node (if the State uses a link-node location reference system) or the milepoint, to the nearest hundredth of a mile, on that highway (if the State uses a milepoint or log point location reference system).

The data then is key-entered into a central computer data base. At present, all States use some form of keypunching to enter data for the accident reports. As of June 1992, only one State was using technology to scan and extract coded information from the accident report. This application is discussed in detail in chapter 3. Several States employ software to translate location information into their location-reference system. Frequently, locational information is found to be inadequate. For example, it may not be possible to identify the location of a specific accident in terms of the State's location reference system. For some States, the resulting accident data base is merged with other data bases including traffic volume data bases and geometric/roadway inventory files before it is made available to the traffic engineer or highway safety analyst in the State highway agency.

For most States, a microfilm copy of the police accident report is generally made at the beginning of the data processing. This microfilm copy provides the permanent hard copy record of the accident and is available for making copies for insurance purposes, requests from private citizens, etc. In most cases, the actual hard copy is not retained by the data center. However, many local police agencies usually keep 3 to 5 years worth of copies of the accident reports on file or in archives at their offices.

The final process in the chain is the data analysis process. As a minimum, all States analyze their accident data to varying degrees to identify locations that have higher than expected accident occurrence. In addition, State highway agencies analyze accident data to evaluate programs and improvement projects that have been implemented. Many State highway agencies analyze accident data as part of subarea studies, corridor planning studies, and environmental impact statements. Frequently, the agency responsible for licensing drivers analyzes accident data to ensure that drivers have financial responsibility (insurance) and to identify problem drivers. Many States generate annual statistical summaries describing the "who, what, when, where, and how many" for reportable traffic accidents in their State. Numerous Federal and other agencies analyze accident data to investigate vehicle defects, highway design and traffic operational practices, driver performance, and other aspects of the driver-vehicle-roadway-environment system.

SUMMARY OF KEY DEFICIENCIES

In addition to discussions with a variety of local and State police agencies, a survey of nine State agencies that are responsible for processing accident reports was undertaken to gain better insights into the accident reporting problems. A variety of problems relating to the entire accident data collection, processing and analysis were identified. These include administrative/staffing problems, problems related to work loads, and problems associated with timeliness (e.g., the time between when the accident occurred and when the data was accessible on a State accident records system). In addition, there are deficiencies associated with the quality of the data. It is important to know where the problem lies so that technologies can be best applied and have the greatest impact. In some cases, the solution to the problem may not be the application of a technology. Rather, the modification of the process or better training may be the best solution.

Administrative/Staffing Problems

Virtually every agency contacted for this study indicated a need for more funding in order to carry out the various tasks required, including data collection, processing the forms, keypunching the data, and providing data to various users. Many claimed that they did not have sufficient resources to manage the large volume of reports that they received. Many local and State police agencies indicated that they did not have sufficient staff to adequately investigate all accidents. Some complained that they did not have sufficient staff to report all accidents that meet the reporting thresholds.

Many police officers feel that accident reports are collected primarily for the insurance agencies. Based on conversations, it appears that when officers fail to realize any benefits from having quality accident data, they often do a very superficial and sometimes poor job in reporting. Much can be and is being done to improve the attitude of the investigating officers at all levels, from the smallest municipality to the State police. For example, Pennsylvania and New York publish newsletters and conduct training workshops.

Based on the States' responses, a broad estimate of the time required to fill out the report form was usually 1 hour for injury accidents and as much as 1½ to 2 hours for fatal accidents. Often the fatal accident reports are accompanied by report supplements with narratives that are much more detailed, and generally the collision diagrams are more carefully drawn.

Timeliness

Estimates of the average time from date of accident to receipt of the report at the designated central State agency processing center are given in table 1. Most often reports from the State police arrive more quickly and regularly than those from the smallest municipalities and county sheriffs.

Table 1. Estimated time from accident to processing at data center.

State	Number of Days From Accident to Arrival at Data Center	Number of Days From Arrival to Creation of Data File	Total Number of Days
California	7 - 30	60	67 - 90
Florida	14 - 30	36 - 48	50 - 78
Michigan	7 - 30	180	187 - 210
Missouri	10	15	25
New Mexico	14 - 21	30	44 - 51
New York	20	120	140
Pennsylvania	39	60	99
Washington	7 - 10	56 - 70	63 - 80
Wisconsin	10 - 14	46	56 - 60

Legibility of Reports

Virtually everyone involved with reading, entering, or using the accident report forms refer to legibility as being a major problem. In most States, the accident report forms are handwritten, often under less-than-ideal circumstances. Efforts directed toward scannable reports would certainly help in this area. Likewise, education of the police with respect to the need for good accident data would help with the legibility of the forms.

Incomplete Reports/Missing Data

Data items that tend to be incomplete are those that are more difficult to observe and/or record. These include such things as the Vehicle Identification Number (VIN), the collision diagram, and the narrative. For States that require the VIN to be recorded on the accident report form, it is estimated that the VIN is missing for as many as 40 to 50 percent of the completed reports. The amount of missing data varies considerably among other variables as well as across States. Missing data may range from 0 to 10 percent for any one variable within a given State. A comparison of two State accident data bases revealed that vehicle model year was missing for only 0.1 percent for one State but 7.8 percent for another State. State agencies should review their own data at least annually to determine where the problems lie and to consider the effect that the application of a technology would have on the problems of missing or incomplete data.

Errors/Inconsistencies

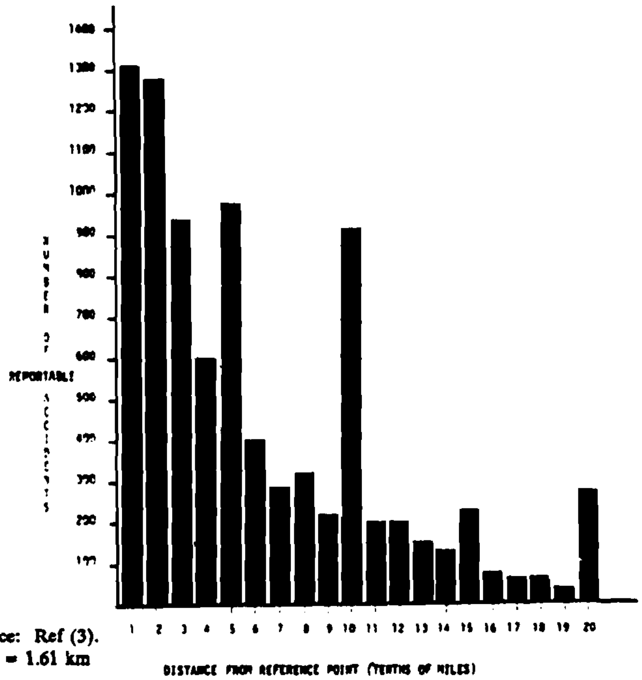
Often, errors can be corrected by the screeners at the data center. Likewise, sometimes computer algorithms can check for inconsistencies. Nevertheless, errors obviously do appear and are often the result of the police officer misunderstanding or forgetting the requirements for a particular data item. Part of the solution for this problem is improved accident instruction manuals for investigating police officers at all levels.

Data Problems

This discussion is broken down by the various general areas of the form such as location, vehicle information, driver/occupant information, etc. Problems cover difficulty in determining the information by the investigating officer, difficulty in accurately recording the data on the form, etc.

Location. This area of the form was the most often mentioned problem for the police officer, for the data coders, and for the traffic engineers that have to utilize the data. It is one of the more difficult portions of the form to complete. To do it correctly often takes considerable time and diligence. The instructions for completing this area of the form are sometimes ambiguous for the police officers with respect to some situations, such as using city street versus route number and vice versa. Many States require that the name of and distance to (or from) the nearest cross road be identified and recorded on the accident report form. Based on a limited sample of police officers for this project, very few measure the distance. Rather, they estimate it based on observation and their judgment of the distance. The effect of "eye-balling" distances is reflected in figure 2. There appears to be disproportionate number of accidents for selected distances from the nearest milepost. The noticeable peaks for 0.5, 1.0, 1.5 and 2.0 mi (0.8, 1.6, 2.4, and 3.2 km) indicate that police officers appear to frequently round off distances.

Some States indicated that the location variable is the most problematic one on the accident report forms received from police agencies. Many indicated that handwriting legibility was a major problem with regards to location information on the report form. Several States indicated that the location information for accidents on ramps and at ramp terminals were less than precise and often insufficient. States also indicated that they often experienced problems in pinpointing accidents in developing areas where new roads are open to traffic but the street inventory files have not yet been updated. Frequently, reference routes are often confused or used inappropriately by the investigating officer. This constitutes a particular problem for loop and other roads that intersect another route in multiple places. For those States with milepost



Source: Ref (3).
1 mi = 1.61 km

Figure 2. Illustration of possible error associated with the accident location as reported by the police.

systems (i.e., roads with milemarker signs placed at spacings of 1 mi (1.6 km) or less), the mileposts, which may be missing, obscured, or nonreadable, are often not used by police officers. In States that use a location index/lookup file on a centralized computer to match location information, general problems included misspellings of street names, different names used by police officers, inaccurate route numbers, among others. For example, police officers may use U.S. 12 for an accident on U.S. 21. In addition, they may use First Avenue for an accident on First Street.

Without good location information in the field, it becomes an added challenge to the location coders as well as the traffic engineers who need to use the data. This, in turn, consumes additional resources of time and money. Several States have indicated that street names create a considerable problem for accident report forms submitted by cities and municipalities. Police officers often use street names rather than the required route number and highway name (or vice versa). Moreover, street names are often misspelled or an improper street name is used. One State indicated that their biggest problem is in the half-urban/half-rural areas. For urban areas, unique names for each intersection are used. For the rural areas, a county route milepost system is used that seems very satisfactory.

In several States, highway department personnel review the individual reports for accidents reported on State highways. They, in turn, determine codes for location, assigning a district number, county number, State route number, postmile, and side of highway to each accident and determine whether it was on a highway, at an intersection, or on a ramp. They indicated that the information is frequently inadequate to determine the specific location of the accident.

Vehicle data. The major problem indicated here is with the Vehicle Identification Number (VIN). A wealth of vehicle-specific information is available from the VIN. Recording the VIN allows subsequent accident analyses of numerous variables including vehicle make, model, model year, body type, type of restraint system, and engine size, among others. Moreover, the use of the VIN allows for a analysis of a multi-State accident data base and thereby facilitates the examination of vehicle-specific safety issues such as the determination of the real-world effectiveness of automatic seatbelts or airbags and the safety disbenefit of passenger vehicle downsizing to achieve fuel economy standards.

More and more States are obtaining VIN information from their vehicle registration file. When the license plate number data from the accident report form is entered into the computer, the license plate number (sometimes along with make/model/year) is used to search registration files. For "hits" (or matches), the registration VIN's are then entered onto the computerized accident file. States that are doing this include New Mexico, Wisconsin, New York, and Pennsylvania. Some other States enter the VIN directly from the form, such as Michigan and Missouri. The State of Washington has VIN on the form but does not enter it into the data. Entering the VIN number on an accident report form is one of the more time-consuming and challenging data element requirements. The VIN is ordinarily located either on the vehicle itself, just inside of the windshield directly in front of the driver, or on the vehicle registration card. For passenger cars, it is a 17-digit alphanumeric code, which increases the opportunity for errors.

As longer and wider trucks are using our highways, more and more are involved in accidents. Generally, these are very serious accidents. Thus, there is a need to know about the causes of such accidents. The data form recommended by the National Governors' Association is challenging and represents an extra form for the police officer to carry. The configuration of the truck, the type of cargo that it is carrying, the gross vehicle weight, and other parameters need to be collected. This represents a significant increase in the demands on a police officer.

Driver/occupant information. Generally, information on all occupants in the vehicle, regardless of injury level, is included on the accident report form. The exception to this is Washington. Typically age, sex, restraint use, and injury level are captured for the driver and occupants. As a minimum, severity of injury is captured by all States. In some States additional information on the nature of the injury (e.g., abrasion, concussion) and location (e.g., head, knee) is included. The major problem is with the police officer being able to determine injury severity with any reliability.

Restraint use information is captured by all States, but is uniformly considered to have limited reliability with the presence of State seatbelt laws. This is due to the fact that most often the police officer asks the motorists if they were wearing their seatbelt. Since there is usually a fine for not wearing it, the motorist is now inclined to indicate that, of course, he or she was using a seatbelt. In North Carolina, the reported seatbelt use in accidents is over 90 percent. This is clearly not the true situation. For the police officer to do a thorough investigation, namely checking for the condition of the belt, the position of the belt (for example, behind the seat), belt-induced injuries, etc., would take an inordinate amount of time. Perhaps telltale signs built into the restraint system would help. For vehicles with airbags, it is obvious whether or not the airbag deployed in the accident. Nevertheless, there will still be an interest in the usage of the manual three-point belts available in vehicles equipped with airbags.

A final area of concern is alcohol and drugs. There is a continuing battle with the variable levels that should be used as well as with reporting actual BAC (Blood Alcohol Content) on the accident report form.

Roadway/environment information. Very few problems were noted with regard to such things as light condition, weather, road surface condition, road surface type, and traffic control.

Collision diagram. The major problem cited is lack of detail in the collision diagram. Police officers often fail to provide important measurements, reference points, identification of vehicle 1 vs. vehicle 2, and so forth. Many of the surveyed States complained about the lack of details in the collision diagrams on the accident report forms. Most often, the investigating officer is requested to indicate the position of the vehicles prior to impact, at impact, and final resting position as well as important dimensions and features that played a role in the accident. More often than not, this level of detail does not exist, and engineering and vehicle design improvements are not as readily suggested from the collision diagrams.

Narrative. This was often regarded as one of the most important parts of the accident report form. The major difficulty cited had to do with the lack of detailed information as well as illegibility of the narrative. Some States, such as Michigan and Pennsylvania, depend on the narrative for information on object struck, weather condition, road surface, alcohol involvement, and other factors. To be done correctly, it is a process that is perhaps one of the more time-consuming tasks in accident reporting.

TECHNOLOGY TO IMPROVE THE ACCIDENT DATA COLLECTION PROCESS

The magnitude of several of the deficiencies described in the previous section can be mitigated through better training of the people who complete accident reports and the people that process the reports and enter the data. Modification of current procedures and processes can also yield benefits. Substantial improvements to the accident data collection process can be achieved through the implementation of new or emerging technologies. The application of technologies can reduce the effort associated with manually performed procedures that are both time consuming and costly. By automating the process through the application of technologies, the quality of the accident data can be improved and the time for the police officer to prepare the accident report can be reduced.

Data processing technologies can be applied to automate the data reduction process at the central data center. Optical scanning and optical disk storage systems can be implemented to improve the accessibility to hard copies of individual accident reports. It should be noted that the provision of optical scanning and optical disk storage systems does not address the major deficiencies described in the previous section. However, if the accident report form is changed, then form reader technologies can be applied to achieve the following objectives:

- Improve the timeliness of accident data.
- Reduce data input errors and emissions.
- Reduce the central agency's costs for coding and keypunching.
- Reduce demands on report processing personnel at central agency.
- Improve information management and accessibility of accident data.
- Improve the overall quality of all data elements.

Form reader systems can scan and extract data from standardized forms. Most students have taken standardized, multiple choice tests, such as the SRA test. The students fill in the appropriate circles on the form. Form reader systems have been used to scan and grade the forms. In much the same way, the format of the State standardized accident report form can be changed so that it is similar to a standardized test form. Then, police officers can fill in the circles that are applicable. At the State data center, the completed forms can be scanned and the data can be extracted directly to create a record for an accident data base. However, while form readers should reduce data processing costs, they will not obviate the need for data coders and key-entry personnel who would still have to code and/or key enter additional information related to location, drivers, passengers, vehicles, and other items.

The use of computers by police officers offer additional benefits compared to the form reader application previously described. Because the police officers would capture all data elements that could be submitted to the central agency on electronic media (e.g., floppy diskettes), this would significantly reduce the cost to code and keypunch data at the central agency. Additional benefits that are expected to result from the use of portable computers include the following:

- Improved legibility of accident reports.
- Improved timeliness of accident data.
- Improved overall quality of all data elements.
- Reductions in the time it takes an officer to complete an accident report.
- Reductions in the time that traffic is affected by an accident.
- Reduction in data input errors and emissions.
- Reduction in the demands on report processing personnel at central agency.
- Improved information management and accessibility of accident data.

The extent of these improvements and reductions will depend greatly upon the individual State or local municipality. This is especially true with respect to missing, erroneous, and inconsistent data.

Technologies are also available that can automate the collection of that driver and vehicle data (e.g., drivers' names, addresses, dates of birth, license plate number, make, model, year, etc.). These identification technologies include magnetic stripes, bar codes, and "smart" cards and automatic vehicle identification (AVI) technologies. The ability to read and electronically capture the information from these devices should further reduce the time it takes for a police officer to complete a report and should further improve the quality of driver and vehicle information included in the accident data base record.

Since 1991, one State has been issuing driver's licenses with a magnetic stripe containing driver information. Two other States will begin issuing licenses with a magnetic stripe in the very near future, and several others are currently investigating this technology. Several vehicle manufacturers are now using bar codes for the vehicle identification number. Several States are investigating the use of bar codes for vehicle registrations, emissions checks, and safety inspections.

As noted in the discussion of key deficiencies, accident location data is often inaccurate or insufficient. Moreover, accident location information is costly to collect in terms of State and local agencies personnel. Location technologies include Loran-C, dead reckoning/map matching systems, cellular phones, and the Global Positioning System. These location technologies, which can be used alone or in combination with computer technologies, can be applied to achieve the following objectives:

- Improve the accuracy of location data.

- Reduce the personnel demands and costs for coding location data at the State data center or at the local level.

CHAPTER 3. DATA PROCESSING TECHNOLOGIES FOR AUTOMATING ACCIDENT DATA REDUCTION

One method of automating the accident data collection process is to apply technology at the State data center. There are two types of technology applications that have already been implemented for processing accident reports. The first application would be to use optical scanners and optical disk storage technology to scan and store images of each page of an accident report. This could be implemented at either a local police agency or the State data center. The second application would be to revise the accident report form so that it resembles the standardized test forms that are given to students in school. Form readers could then be implemented at the State's accident report processing center to scan completed accident report forms and create a data base record for that accident report. This application would reduce the amount of information that needs to be keypunched and thereby reduce data entry time, errors, and associated costs. These two applications are discussed in greater detail in the succeeding sections.

OPTICAL SCANNERS TO SCAN AND STORE ACCIDENT REPORTS

Optical scanners and optical disk storage systems can be used to scan and store accident reports. Handwritten and typed police traffic accident reports can be scanned using optical scanners and the images of each page of a report can be stored on an optical disk system. These systems can be implemented at the State data center or the local police agency's data processing section. At the local level, these systems can be used to automate the records section of a police department.

Application of Optical Scanners in Virginia and Anaheim

The Virginia Department of Transportation (VDOT) currently uses an optical disk technology for the storage and retrieval of accident reports. In Virginia, all police accident reports are sent to the Virginia Department of Motor Vehicles (DMV). The DMV key enters most information on the completed accident report form, except for link-node location. The DMV then sends the reports to VDOT, who also has access to the accident records data file created by the DMV. The police traffic accident report forms are then batched and scanned into an optical disk system by VDOT. Data coders then use both the digital image of the narrative and sketch and the accident data file created by DMV to codify the node and offset for the accident location and add that data to the accident data base record. Over a year, approximately 140,000 to 150,000 accident reports are scanned. Figure 3 shows a scanner at the work station. Typically they are about the same size as a desktop laser printer.

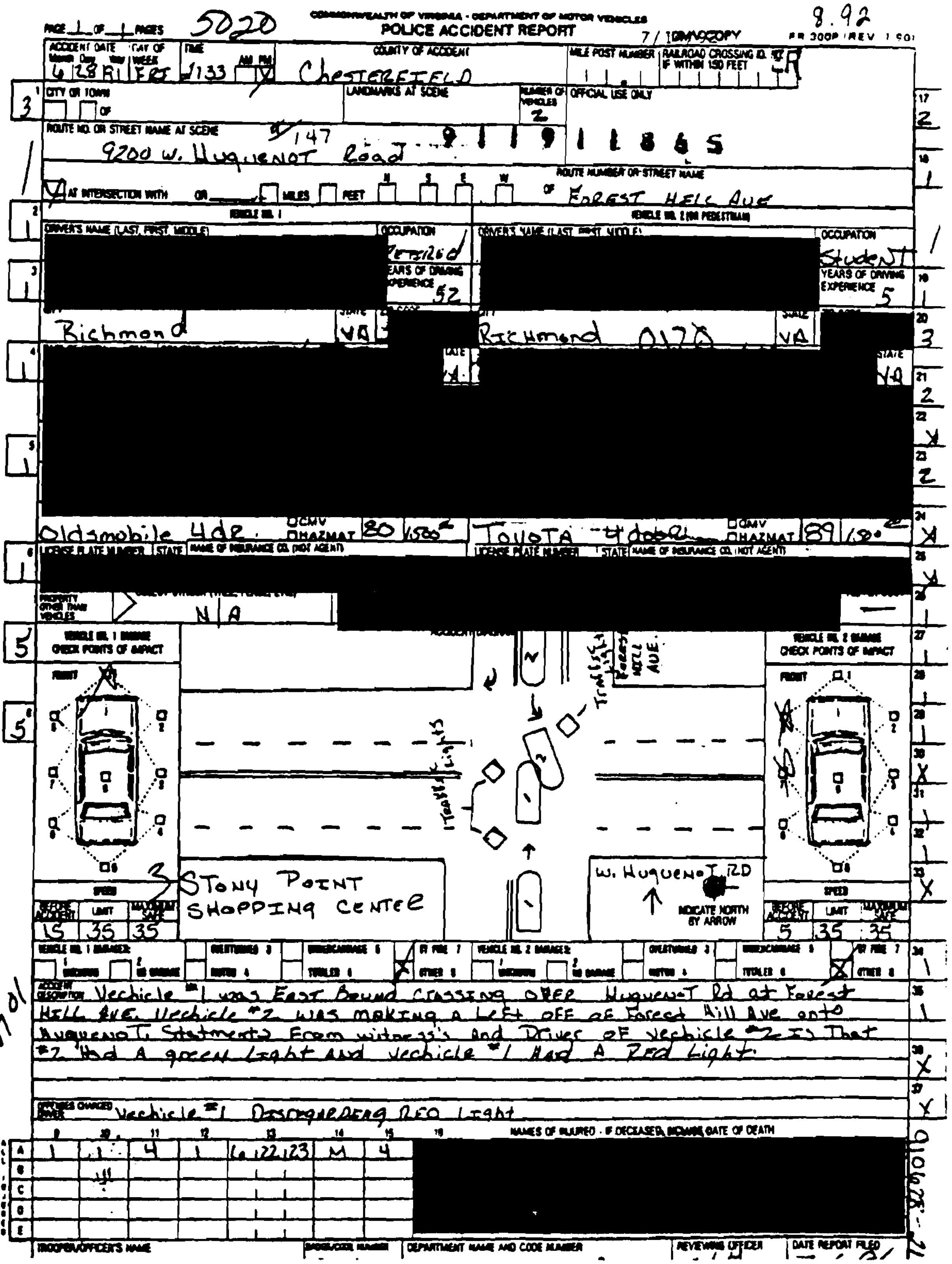
The current system has the capacity of storing 600,000 images. VDOT has the capability of retrieving and printing a computer-generated copy of the entire report for safety studies and in response to requests from their district offices. Figure 4 is a sample of a hard copy of a police accident report that was generated by the system. The software allows for personal information about drivers, vehicle owners, and injured persons to be blanked out. Thus, in addition to the standard statistical information available from the accident data base, VDOT safety analysts have

Figure 3. An optical scanner used by VDOT.

easy access to the images that contain the entire narrative and sketch for selected traffic accident reports.

Approximately 2,000 to 3,000 accident reports are retrieved each year. VDOT indicates that prior to the system, technicians would spend as much as 60 percent of their time at file cabinets or at the copying machine. The system has substantially reduced photocopying costs, cut down on some types of errors associated with location, and improved the efficiency of location coders through the use of software that assists in identifying nodes and distances. Prior to the implementation of the new system, it was common for the original accident reports to have been pulled from the files and never returned or returned after a long time period. When technicians went searching for reports, they often found an "out-of-file" card and no report. The system has virtually eliminated this "out-of-file" problem. Although the imaging terminals are currently in Richmond, the system has the capability to be accessed from other parts of the Commonwealth. VDOT indicates that most of the requests are for intersection accidents from VDOT District personnel.

The police department for the city of Anaheim, California, is currently using an optical disk system to scan and store all their police reports, including their traffic collision reports. The system has greatly improved accessibility to files, reduced staff demands for filing and retrieving files, and enhanced the capability to process information within the police records division. The city of Anaheim indicated that their system is configured to sort, search, and extract the images that comprise the report on the basis of seven key entered fields. The police department generates a copy for the city's traffic engineering department and also sends one copy to the central office of the California Highway Patrol in Sacramento. The police department can use the system to generate additional copies of specific accident reports in response to specific requests.



PAGE 1 OF 1 PAGES 5020

COMMONWEALTH OF VIRGINIA - DEPARTMENT OF MOTOR VEHICLES

POLICE ACCIDENT REPORT

9.92

7 / 1DMV9COPY

FR 300P (REV 1 90)

ACCIDENT DATE 6 28 91 DAY OF WEEK FRI TIME 1133 AM PM

COUNTY OF ACCIDENT Chesterfield

CITY OR TOWN

LANDMARKS AT SCENE

NUMBER OF VEHICLES 2

OFFICIAL USE ONLY

ROUTE NO. OR STREET NAME AT SCENE 9200 W. Huguenot Road 147

9 1 1 9 1 1 8 4 5

AT INTERSECTION WITH OR MILES FEET N S E W OF ROUTE NUMBER OR STREET NAME Forest Hill Ave

VEHICLE NO. 1

DRIVER'S NAME (LAST, FIRST, MIDDLE) [redacted]

OCCUPATION Retired

YEARS OF DRIVING EXPERIENCE 52

Richmond VA [redacted]

VEHICLE NO. 2 (OR PEDESTRIAN)

DRIVER'S NAME (LAST, FIRST, MIDDLE) [redacted]

OCCUPATION Student

YEARS OF DRIVING EXPERIENCE 5

Richmond 0170 VA [redacted]

Oldsmobile 4dr. CMV HAZMAT 80 1500

Toyota 4door CMV HAZMAT 89 1500

LICENSE PLATE NUMBER STATE NAME OF INSURANCE CO. (NOT AGENT) [redacted]

PROPERTY OTHER THAN VEHICLES N/A [redacted]

VEHICLE NO. 1 DAMAGE CHECK POINTS OF IMPACT

VEHICLE NO. 2 DAMAGE CHECK POINTS OF IMPACT

Traffic Lights

Forest Hill Ave.

Stony Point Shopping Centre

W. Huguenot RD

INDICATE NORTH BY ARROW

SPEED: BEFORE ACCIDENT 15 LIMIT 35 MAXIMUM SAFE 35

SPEED: BEFORE ACCIDENT 5 LIMIT 35 MAXIMUM SAFE 35

VEHICLE NO. 1 DAMAGES: OVERTURNED UNDERCARRIAGE BY FIRE TOTALED OTHER

VEHICLE NO. 2 DAMAGES: OVERTURNED UNDERCARRIAGE BY FIRE TOTALED OTHER

ACCIDENT DESCRIPTION Vechicle #1 was East Bound crossing over Huguenot Rd at Forest Hill Ave. Vechicle #2 was making a left off of Forest Hill Ave onto Huguenot. Statments from witness's and Driver of Vechicle #2 Is That #2 Had A green Light and Vechicle #1 Had A Red Light.

OFFENSES CHARGED DRIVER Vechicle #1 Disregarding Red Light

NAMES OF INJURED - IF DECEASED, INDICATE DATE OF DEATH

	9	10	11	12	13	14	15	16
A	1	1	4	1	6 122 123	M	4	[redacted]
B								
C								
D								
E								

TROOPER/OFFICER'S NAME BADGE/CODE NUMBER DEPARTMENT NAME AND CODE NUMBER REVIEWING OFFICER DATE REPORT FILED

Figure 4. A computer-generated hard copy of a scanned accident report from VDOT's system.

Anticipated Benefits

In a majority of States, many safety analysts and traffic engineers do not have access to hard copies of individual accident reports. If they wish to obtain hard copies, then they or clerical personnel at the records division must manually search through file cabinets for the needed reports, pull the appropriate originals, make copies of each page of the report, and then refile the original report. Currently, many safety assessments and analyses are performed without the benefit of reviewing the sketches and narratives on hard copies of the reports. With this type of application of optical scanning and optical disk storage systems, a safety analyst could have easy access to individual reports. The result would be an improvement in the quality and depth of safety analyses performed by traffic engineers at the State agency. In addition, optical disk storage systems can replace microfilming and greatly reduce the problems associated with storage and management of large amounts of original or hard copies of police reports. Figure 5 shows an optical disk and a drawer full of accident reports. One laser optical disk can hold as much information as one, four-drawer cabinet.

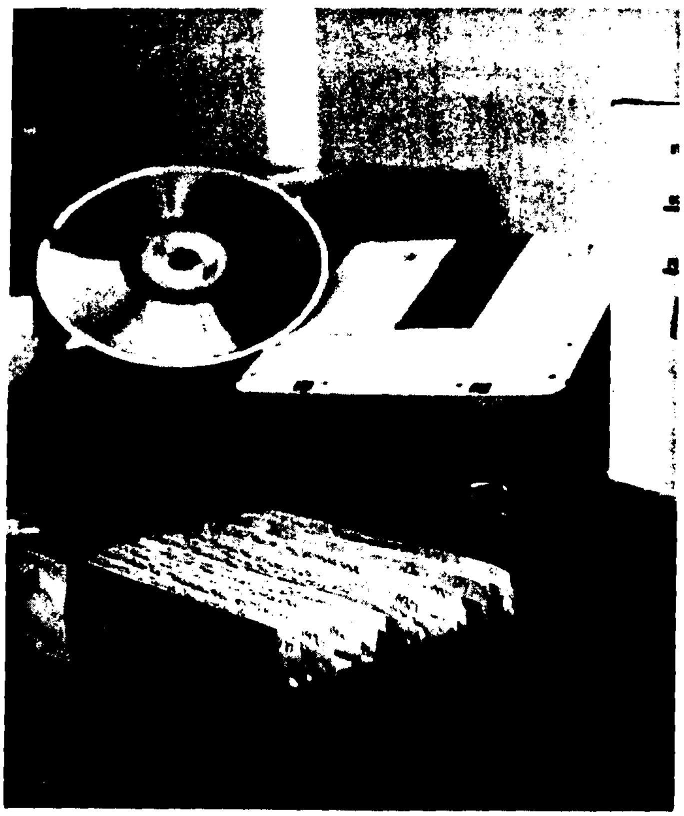


Figure 5. An optical disk as an alternative storage media.

Limitations/Disadvantages

The two applications of optical scanning technology previously described basically were attempts to improve accessibility to hard copies of police reports, improve the efficiency and processing capabilities of a records division, and move towards a paperless operation by reducing the amount of paper that needs to be stored and kept on file. However, this particular application of optical scanning and optical disk storage technology, as described, does not reduce the costs to code and keypunch information on the completed report. Moreover, this technology application does not improve the timeliness of the data, does not improve the overall quality of the data in the accident records data base, and does not reduce the time for the police officer to complete a report.

One way to overcome these deficiencies would be to employ systems with optical character recognition software that can interpret and extract handwritten information directly from a scanned form and input that data into an accident records data base. There are optical scanning systems that are on the market today that have character recognition capability. However, most of these systems require a particular format for the form, a minimum letter height, and standardized block lettering style. The current formats of almost all State accident report forms do not lend themselves to optical character recognition. As of today, it is not feasible for optical scanning systems to scan and extract data from the current handwritten forms. The state-of-the-art of optical character recognition is not to a point where it can extract all the necessary data from existing State accident report forms. Moreover, if data coders and keypunchers are already experiencing legibility problems with the manner in which State accident report forms are completed by police reports, then it is highly unlikely that optical character recognition software will be able to interpret police officers' handwriting. In order to take advantage of optical scanning and optical character recognition technology, the State accident report form must be revised.

FORM READER SYSTEMS TO EXTRACT DATA FROM REFORMATTED ACCIDENT REPORT FORMS

The application of form reader technology can reduce the coding and keypunching efforts and the associated costs incurred at the State data center. However, the application requires that the format of the State traffic accident report form also be changed. Hence, the implementation of this technology application is dependent on the central State agency that is responsible for the administration and maintenance of the statewide accident report form.

Application of Form Readers in Michigan

The Michigan State accident report form that was used prior to January 1992 is shown in figure 6. Police officers had to circle appropriate codes for weather, light, road surface, and whether the road was divided, limited access, or other. In addition, they had to circle Y or N for variables including construction zone, investigated at scene, helmet use (for motorcyclists), hazard citation, other citation, driver re-exam, vision obstructed, vehicle defect, vehicle driveable, fuel leakage, vehicle fire, truck cargo spillage. They also had to fill in information for the rest of the form. At the State data center, coders then had to enter codes for 34 items on the side of the form. In addition, Michigan used a supplemental form for fatal accident reports.

In April 1991, Michigan began the task of drastically revising their police accident report form so that most of the fields could be scanned by form readers. The Office of Highway Safety Planning

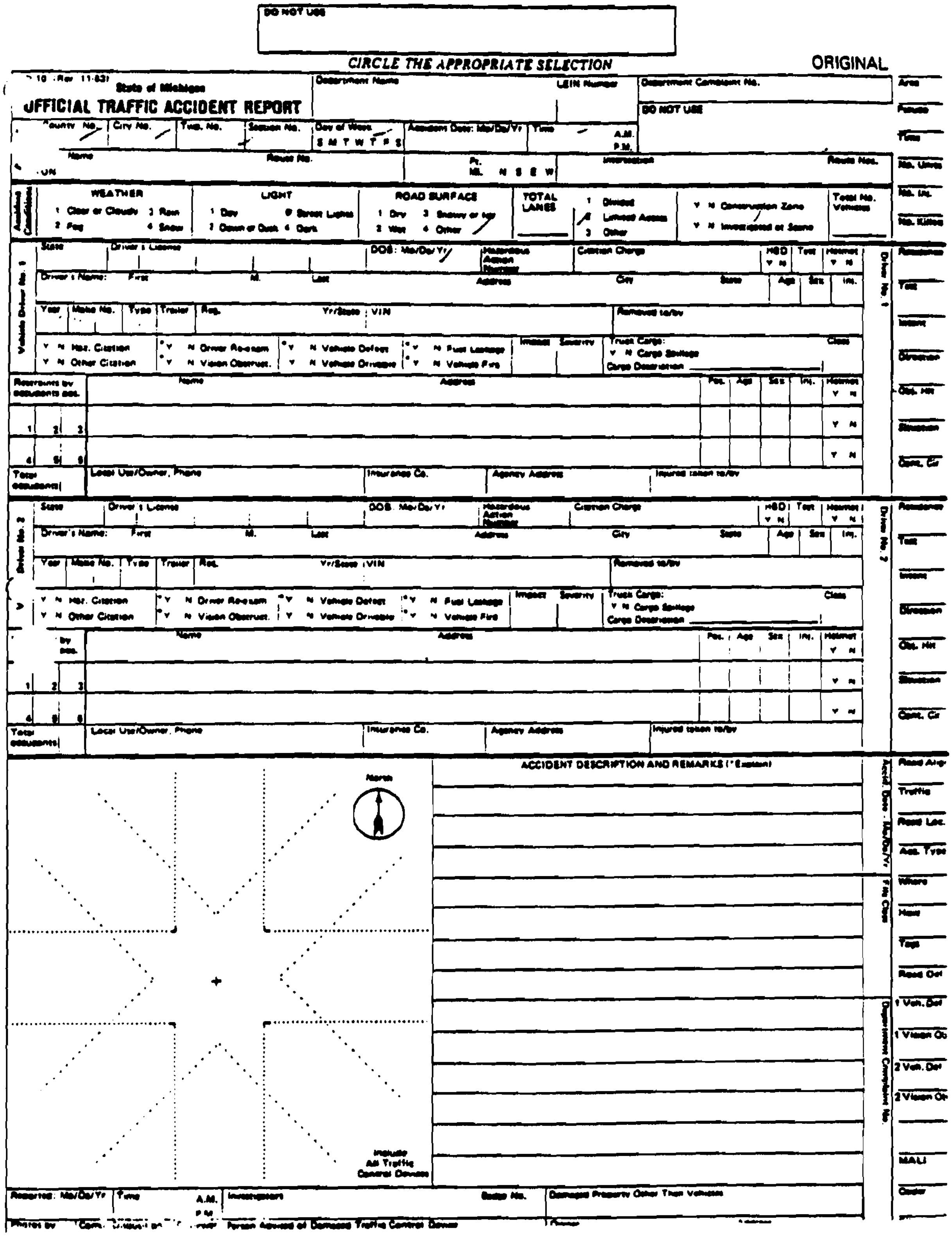


Figure 6. Michigan's old accident report form.

within the Michigan Department of State Police had the responsibility for developing the new form. They set a "fast track" schedule to implement the new form statewide on January 1, 1992. The front and back sides of this Michigan Traffic Crash Report form (UD-10) included elements from the old report form, elements for the National Governors Association truck and bus data requirements, and all NHTSA's Critical Automated Data Reporting Elements (CADRE) for highway safety analysis. The form was designed to be "self-coding." A supplemental two-page instruction sheet was developed. During this time period in 1991, Michigan made the decision to exclude the narrative and the sketch from the UD-10 report form. The rationale was that the investigating officer could utilize a supplemental form to prepare a narrative and/or a sketch.

Form readers were purchased and installed to scan and extract data for approximately 80 percent of the elements (i.e., 158 "mark-sensed" data fields). The variables that have been converted to "fill-in-the-circle" entries included weather, light, road (surface) condition, month, day, year, hour, minute, total number of lanes, county, city/township, relation to roadway, area, speed limit, occupant characteristics (e.g., sex, alcohol/drugs, injury, seat position, restraint use, ejection), vehicle characteristics (e.g., vehicle type, use, drivability, defects, hazardous material, damage area and severity, direction of travel), sequence of events, and UD-10 form number. Scanning mark-sensed fields reduced the need for data coders to review reports and codify selected data elements. However, it did not eliminate the need for key-in personnel. Michigan indicated that after the initial screening and scanning of the form, key-in operators enter data for the remaining 20 percent of the form. Then the keyed-in data is merged with the data extracted from scanning the form. The data elements that are key-entered include the following:

- The accident location, which includes the road name/number, and distance and direction to nearest intersection.

- The names, addresses, dates of birth, license numbers, positions, restraint system status, and ambulance/hospital for all drivers.

- The registration number and State for each vehicle.

- The names, dates of birth, positions, restraint system status, and ambulance/hospital for all injured passengers.

- The name and address of the commercial vehicle carrier and the type and axles per unit for all trucks and buses.

A series of 26 training sessions were held throughout the State. Those persons responsible for revising the form and/or responsible for data entry instructed police training officers about filling out the new form and the revised instruction manual. On January 1, 1992, the State of Michigan began using a new statewide accident report form. The learning curve was apparently relatively short. It was generally reported that there was mass confusion for the first month or so. After that, the police officers had gotten used to the new format and were quite satisfied with it.

The use of scanners began on approximately March 1, 1992. The scanners do not have the ability to recognize handwritten letters or numbers nor do they have the ability to extract text information from the form for inclusion into the accident records data base. However, Michigan's form reader can interpret the "bubbles," which are the elliptical shapes that are filled in by police officers on the UD-10 report form. According to the Executive Director of the Office of Highway Safety Planning, it cost about $75,000 to update and purchase the necessary new equipment, which included one scanner that cost about $20,000 and five personal computers for data entry of keyed information and the merging of scanned and keyed data. The scanner is a table top model capable of scanning 3,000 forms per hour. This equipment is expected to accommodate their 400,000 annual accidents.

After a break-in period with the expected learning curve, the form was beginning to yield an improvement in timeliness and a reduction in data processing demands, although the effectiveness has not as yet been measured or quantified. However, some users of the accident data, particularly those in the traffic engineering community, emphasized how the loss of the narrative and sketch had adversely affected the accident data reporting process. Although the supplemental form is used mostly for fatal accidents, some police departments adopted a policy that both forms will be collected for <u>all</u> accidents because their needs were not being met with the new UD-10 form. Michigan therefore will reinstate the narrative and sketch on the revised UD-10 form that is scheduled to be implemented in January 1993. The front and back sides of the revised form (1/1/93) is presented in figures 7 and 8. As can be seen, this revised form has a 3.9-in by 4.7-in (99-mm by 119-mm) block of space for the narrative and sketch. Although this is decidedly less space for the collision diagram than is generally available, it was felt to be adequate. Training for the revised form (1/1/93) will also include a video on filling out the form, which will be distributed statewide for use at the local level.

Implementation Steps

Implementation of a form reader system and revised accident form could consist of the following steps:

1. Develop a revised/reformatted State accident report form.

2. Perform an evaluation of the new report form using a selected sample of State and local police agencies.

3. Finalize, produce, and distribute new report forms.

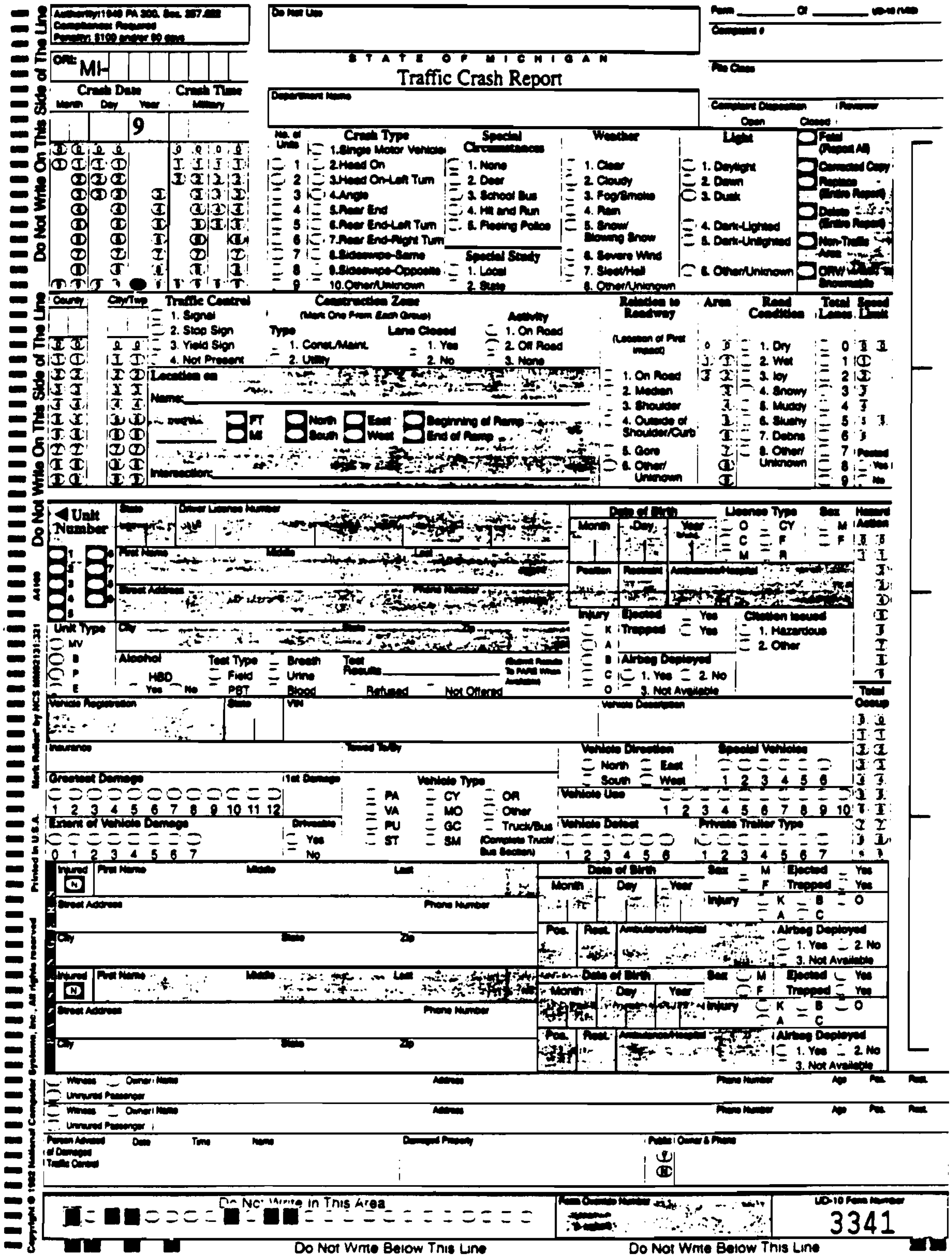
4. Develop the specifications and requirements for the form readers and associated computer hardware and software modifications.

5. Train police agency trainers to train their police officers to properly complete and handle the new report form.

6. Purchase, install, and test new equipment.

7. Develop and implement equipment and procedural changes at the State data center.

8. Mandate the use of the new report form on a specific date.



Authority: 1949 PA 300, Sec. 257.622
Compliance: Required
Penalty: $100 and/or 90 days

Do Not Use

STATE OF MICHIGAN
Traffic Crash Report

Department Name

ORI: MI-

Crash Date: Month, Day, Year (9)
Crash Time: Military

Complaint #
File Class
Complaint Disposition: Open, Closed
Reviewer

No. of Units: 1, 2, 3, 4, 5, 6, 7, 8, 9

Crash Type: 1. Single Motor Vehicle; 2. Head On; 3. Head On-Left Turn; 4. Angle; 5. Rear End; 6. Rear End-Left Turn; 7. Rear End-Right Turn; 8. Sideswipe-Same; 9. Sideswipe-Opposite; 10. Other/Unknown

Special Circumstances: 1. None; 2. Deer; 3. School Bus; 4. Hit and Run; 5. Fleeing Police

Special Study: 1. Local; 2. State

Weather: 1. Clear; 2. Cloudy; 3. Fog/Smoke; 4. Rain; 5. Snow/Blowing Snow; 6. Severe Wind; 7. Sleet/Hail; 8. Other/Unknown

Light: 1. Daylight; 2. Dawn; 3. Dusk; 4. Dark-Lighted; 5. Dark-Unlighted; 6. Other/Unknown

Fatal (Report All); Corrected Copy; Replace (Entire Report); Delete (Entire Report); Non-Traffic Area; ORV/Snowmobile

County; City/Twp

Traffic Control: 1. Signal; 2. Stop Sign; 3. Yield Sign; 4. Not Present

Construction Zone (Mark One From Each Group)
Type: 1. Const./Maint.; 2. Utility
Lane Closed: 1. Yes; 2. No
Activity: 1. On Road; 2. Off Road; 3. None

Location on; Name; FT / MI; North / South; East / West; Beginning of Ramp / End of Ramp; Intersection

Relation to Roadway (Location of First Impact): 1. On Road; 2. Median; 3. Shoulder; 4. Outside of Shoulder/Curb; 5. Gore; 6. Other/Unknown

Area

Road Condition: 1. Dry; 2. Wet; 3. Icy; 4. Snowy; 5. Muddy; 6. Slushy; 7. Debris; 8. Other/Unknown

Total Lanes; Speed Limit; Posted: Yes / No

Unit Number: 1, 2, 3, 4, 5
State; Driver License Number; Date of Birth: Month, Day, Year; License Type: O, C, M, CY, F, R; Sex: M, F; Hazard Action
First Name; Middle; Last
Position; Restraint; Ambulance/Hospital
Street Address; Phone Number
City; State; Zip
Injury: K, A, B, C, O; Ejected: Yes; Trapped: Yes
Citation Issued: 1. Hazardous; 2. Other
Unit Type: MV, B, P, E
Alcohol: HBD Yes / No
Test Type: Field, PBT, Breath, Urine, Blood
Test Results; Refused; Not Offered
Airbag Deployed: 1. Yes; 2. No; 3. Not Available
Vehicle Registration; State; VIN; Vehicle Description; Total Occup.
Insurance; Towed To/By
Vehicle Direction: North, South, East, West
Special Vehicles: 1 2 3 4 5 6
Greatest Damage: 1 2 3 4 5 6 7 8 9 10 11 12
1st Damage
Vehicle Type: PA, VA, PU, ST, CY, MO, GC, SM, OR, Other, Truck/Bus (Complete Truck/Bus Section)
Vehicle Use: 1 2 3 4 5 6 7 8 9 10
Extent of Vehicle Damage: 0 1 2 3 4 5 6 7
Driveable: Yes, No
Vehicle Defect: 1 2 3 4 5 6
Private Trailer Type: 1 2 3 4 5 6 7

Injured (N); First Name; Middle; Last; Date of Birth: Month, Day, Year; Sex: M, F; Ejected: Yes; Trapped: Yes
Street Address; Phone Number; Injury: K, A, B, C, O
City; State; Zip; Pos.; Rest.; Ambulance/Hospital; Airbag Deployed: 1. Yes; 2. No; 3. Not Available

Injured (N); First Name; Middle; Last; Date of Birth: Month, Day, Year; Sex: M, F; Ejected: Yes; Trapped: Yes
Street Address; Phone Number; Injury: K, A, B, C, O
City; State; Zip; Pos.; Rest.; Ambulance/Hospital; Airbag Deployed: 1. Yes; 2. No; 3. Not Available

Witness / Owner / Name; Uninjured Passenger; Address; Phone Number; Age; Pos.; Rest.
Witness / Owner / Name; Uninjured Passenger; Address; Phone Number; Age; Pos.; Rest.

Person Advised of Damaged Traffic Control; Date; Time; Name; Damaged Property; Public / Owner & Phone

Do Not Write In This Area
Form Override Number
UD-10 Form Number: 3341

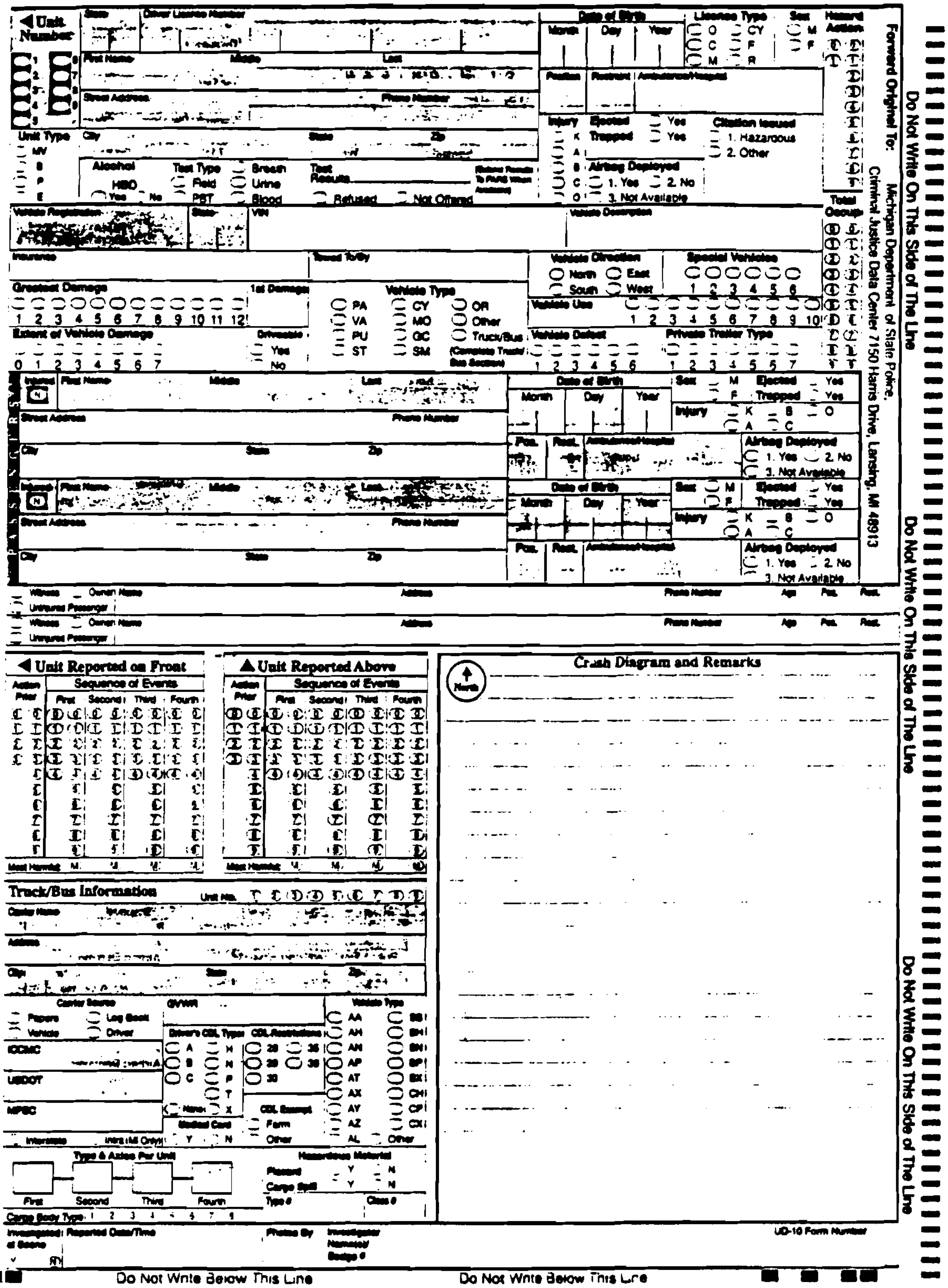
Do Not Write Below This Line — Do Not Write Below This Line

Do Not Write On This Side of The Line

Copyright © 1992 National Computer Systems, Inc., All rights reserved. Printed in U.S.A. Mark Reflex® by NCS

(Original size 8 1/2 in x 11 in (216 mm x 279 mm))

Figure 7. Front side of Michigan's revised accident report form.



(Original size 8 1/2 in x 11 in (216 mm x 279 mm))

Figure 8. Back side of Michigan's revised accident report form.

9. Receive and scan completed reports. Receive feedback from all users. Evaluate and assess the operation.

10. Identify additional changes that are required to improve the operation or overcome problems encountered. Implement those changes.

It is imperative that the new State accident report form be implemented statewide and simultaneously by all police agencies. States that require one side of a single form resulting from coded entries around the perimeter of the form (e.g., New York State) would need at least front and back of a new form. Most of the traditional data elements can be converted to scannable entries. However, text-type variables (e.g., driver's name, location) and numeric entries (e.g., driver's license number) need to be entered as previously.

One important point needs to be made about revising the accident report form to allow "fill-in-the-circles." The designated central agencies in most States do not and are not required to "capture" the narrative or the sketch. In fact, many central State agencies that process the accident data do not even use the narrative or sketch. Consequently, in an effort to maximize the capture of statistical data that could be collected through use of fill-in-the-circles, some States may decide to exclude the narrative and the sketch. However, many traffic engineers and safety analysts who are end users of these data argue that the loss of the narrative and the sketch would adversely affect the accident data reporting and analysis process. Without the narrative and sketch, it will become more difficult to analyze spot accident locations, identify the dynamics of the accident, assess the relative contribution of factors to the accident, and to better understand the cause-and-effect relationships. It is strongly recommended that space be retained on the form for a narrative and a sketch.

Based on experience in looking at thousands of collision diagrams and narratives, a 3-in by 8.5-in (76-mm by 216-mm) block of space appears to be sufficient for the narrative and sketch for the vast majority of accidents, perhaps 80 to 90 percent in States with reporting thresholds of $500 property damage and/or personal injury. Several police officers indicated that this would be adequate for their purposes. One possible division of this space is to provide a 4-in by 3-in (102-mm by 76-mm) empty box for the sketch and a 4-in (102-mm) wide by 3-in (76-mm) high area with 12 "ruled" lines [e.g., 0.25-in (0.6-mm) lines] in between for the narrative. For complicated interchanges or for involved narratives, additional space will be required. Most States have provisions for a supplemental page(s) to be attached to the accident form. These can and should be utilized in these situations.

Equipment

It is important to understand that some form reader systems do not have the capability to interpret text. Many systems have been designed for processing 3.25- to 4.25-in (82- to 107-mm) wide forms or cards. These systems, which are commonly used for educational testing, electronic betting, State lottery games, pari-mutuel betting, time sheets, and electronic voting (e.g., balloting for baseball's all star teams), generally do not have the capability to interpret text. They utilize photoelectric image resolution techniques that detect variations in the reflective light intensity that exists between the background and the marked field (e.g., circle, oval, square, rectangle, etc.). There is one major disadvantage to these types of systems that do not have optical character recognition software. There are several data fields on the accident report form that cannot easily be converted to mark-sensed fields. For example, driver's address would require a large amount of space for multiple alphanumeric characters. Accident location information (e.g., town/city name, road name/number, distance and direction to nearest intersection, etc.), driver information (e.g., name, address, date of birth, license number, etc.), injured person information (e.g., name, date of birth, seat position, restraint system status, and ambulance/hospital), vehicle information (e.g., license plate number, registration number and State), and commercial vehicle information (e.g., name and address of the carrier, etc.) would require additional keypunching. In order to achieve the maximum effectiveness of scanning, then alphanumeric information should also be extracted by the system. The following discussion pertains to systems that have optical character recognition capability.

Typically, a form reader/optical scanner system with optical character recognition capability consists of the following components:

- Form reader.
- Processor and logic unit.
- Personal computer.

The form reader houses an input tray that allows a stack of forms to be processed as a batch. Alternatively, single sheets can be fed into the form reader as well. Once processed, the forms are collected in an output tray. Some form readers contain a page numbering device that can print batch and identification numbers on each form as it is processed. The batch number and identification number are useful for quality control and subsequent data editing. States typically assign unique accident case numbers to each accident report. The automatic assignment of batch and identification numbers, which are programmable by the operator, is an efficient way to accomplish this task. For some form reader systems that are currently available, the form reader scans the page and creates a digital picture of the form, which is then processed by software contained in the processor and logic unit. For some manufacturers, this processor and logic unit is a separate piece of hardware connected to the form reader. The processor and logic unit analyzes the scanned form and performs the optical character recognition to extract the data.

The personal computer controls the operation of the system. The personal computer contains the software that allows the user to initiate a batch of forms to be read and controls the form reader. This software is designed for ease of use and is usually menu-driven. The personal computer is connected to the form reader through a cable.

The software on the personal computer also provides the capability to correct data as pages are being processed by the form reader or after a batch has been completed. Some systems allow for interactive editing. If these systems cannot correctly interpret data on an area of the form, then an image of the area is displayed on the screen exactly as it appears on the form. The user can then make the appropriate corrections as necessary. With some systems, thresholds can be established for each field on the form that will control the "flagging" of errors by the system. Software can also be customized to perform validation checks before the batch is accepted and stored in the data base on the computer's hard disk. Typically, the data are stored in ASCII-formatted files. The structure of the ASCII files can be modified by the operator, if needed.

The capability to retain and store digital images of the individual pages of the accident report form is not available with all form reader systems. Some form reader systems offer the capability of storing images at no charge for certain graphical formats. If other graphical formats are desired (i.e., higher resolution), an additional cost is incurred. For example, in the Scan-Optics, Inc. EasyReader 1720 form reader system, the capability to store digitized images of scanned forms in CCITT (Consultive Committee on International Telephony and Telegraphy) Group 3 format is included with the system. To store CCITT Group 4 formatted forms costs an additional $5,000. The CCITT Group 4 format is the standard format currently accepted by the Federal Government for facsimile machines. Due to the large amount of disk space needed to store the digitized accident report forms, high-capacity hard disks or optical disks may be required. More disk space is required for high resolution formats.

One of the appealing aspects of this technology is that aside from the equipment required by the central State agency, no additional equipment would need to be purchased. Specifically, the State would not have to purchase or provide additional equipment to the numerous police agencies throughout the State. Furthermore, the individual police agencies would not have to purchase or maintain additional equipment at their own cost. Local agencies could, however, purchase their own form reading system and scan their completed report forms before they send them to the State data center.

Implementation Costs

While the equipment costs were on the order of $75,000, Michigan could not provide cost figures for the 26 training sessions or the numerous telephone inquiries involved in answering the myriad of ensuing questions. It is estimated that the costs for Michigan to revise the form should have been comparable to the costs usually involved in revising the form, which most States do every 5 years or so.

There is a wide variety of costs for a complete system with optical character recognition capability. Prices range from $50,000 to over $250,000. Processing speeds can range from 400 forms/hour to 12,000 forms/hour. Manufacturers also offer maintenance agreements that cover any problems that may arise. Prices for maintenance agreements tend to vary as well. Typically, one complete system at the central agency would be adequate for an average State. Other States may require several form reader systems to handle large processing loads.

Price comparisons are presented in table 2 for several manufacturers of form reader systems with optical character recognition software. It should be noted that the prices shown include training and hardware/software setup. Some manufacturers offer quantity discounts ranging from 5 to 20 percent for the purchase of multiple form readers, work stations or systems. For States processing a very large volume of accident reports, some form reader systems offer additional hardware and software that allow multiple work stations to be networked together to utilize a single form reader. This allows each work station to simultaneously process a different batch of accident report forms or process different portions of a single batch of accident report forms. For example, the UNIX-based system offered by AEG Recognition Systems can be configured for up to four networked work stations. Each additional data entry work station would cost approximately $12,500. In addition, a server work station would also be required to control the networking functions. The server work station would cost approximately $10,000. The range of processing speeds for various models shown in table 4 is based on the size and complexity (i.e., number of data fields) of the form. It is emphasized that these are not the only manufacturers of this technology and are identified solely to provide cost information.

Table 2. Price comparisons of form reader systems with optical character recognition.

Manufacturer	Model	Processing Speed	Complete System Cost	Maintenance Contract Cost
AEG Recognition Systems	DOS-based System	400-1,400 pages/h	$110,000	$7,600/yr
AEG Recognition Systems	UNIX-based System	400-1,400 pages/h	$135,000	$9,300/yr
Cognitronics Imaging Systems, Inc.	CIP/200	2,000-4,500 pages/h	$50,000	$6,000/yr
Scan-Optics, Inc.	EasyReader 1720	900-1,800 pages/h	$90,000	$12,000/yr
Scan-Optics, Inc.	ReliaReader	10,500-12,000 pages/h	$250,000	$25,000/yr

Anticipated Benefits

The implementation of a statewide accident report form with mark-sensed fields and form reader system at the State data center is projected to yield the following benefits:

- Improved timeliness and legibility of reports.
- Reduced data input errors and omissions.
- Reduced coding and keypunching costs by the central data processing agency.
- Improved information management.
- Improved accident reporting with respect to accuracy of data and time it takes to complete the form.

The primary benefits to the local and State police agencies would be legibility and savings in time spent filling out the form. A preliminary estimate from Michigan's initial experience is that it takes about 10 percent less time to complete the new UD-10 report form compared to their old form.

Agencies that have the responsibility to create and maintain the accident records data base would benefit the most. It is anticipated that the data entry section of the Michigan State Police Data Center will drop from 33 persons down to 15 when they catch up with the 1991 backlog. And once caught up, they anticipate having the accident data computerized within 45 days of the accident; their former goal was 90 days. Currently, with the backlog, they are 170 days behind. Several Michigan employees indicated that they were thrilled with getting rid of the backlog.

For the user agencies, the data will not only be more timely, but it should be more accurate. There will be less coding required at the State data center and, without the human keypuncher, there will be virtually no input errors and omissions. With respect to the quality of data, Michigan has not conducted any analysis of the 9,000 new UD-10 forms that have been scanned to date or performed any quality control analyses of hard copies collected at the State Police Data Center.

Once the form is implemented, a local agency may also choose to implement its own form reader system. The Kalamazoo County Roads Commission is in the process of scanning accident reports collected by the Kalamazoo County Sheriff's Department, the city of Kalamazoo Police Department, and the city of Portage Police Department. The reports are scanned using the University of Western Michigan's grading scanners. The Roads Commission has done so in order to have access to their own accident data within a few days of the accident. They maintain an accident data base that is separate from Michigan's State accident data base. After they have scanned the reports, the Kalamazoo County Roads Commission send the report forms to the Michigan Department of Transportation (DOT) in East Lansing where they are again scanned. The Kalamazoo County Roads Commission currently does not send a computer file of its scanned accident reports to the Michigan DOT, but they could. The fact that the DOT scans the report a second time does not preclude the possibility that they would accept the data in electronic media at a later date.

Limitations/Disadvantages

It should be clearly understood that implementation of this type of technology will not obviate the need for data coders or data keypunchers. Location information is one of the fields that requires coding. Road names, route numbers, and milepoints or node numbers, will still need to be coded and keypunched. The magnitude of additional keypunching will depend on whether or not the form reader system has optical character recognition capability. For example, the system implemented in Michigan does not have this capability; consequently, they have to keypunch all alphanumeric data that was not converted to mark-sensed format. Specifically, the names and addresses of driver(s) and injured passengers, the date(s) of birth, the driver's license numbers, and the name(s) of hospital where injured people were taken also require keypunching. Even if the system has optical character recognition (OCR) software with error traps and edit flags can be designed into the processing software, this will not make data keypunchers obsolete.

OCR software currently cannot recognize and interpret the wide variety in police officers' handwriting styles. In all likelihood, it will be years before that capability is sufficiently developed to be adequate for everyday use by all officers. Consequently, personnel will be needed to perform quality control checks of the data, edit the data after the report is scanned, and enter data that is not recognized by the software.

Another potential limitation is related to the introduction of a new accident report form to be used statewide. Ideally, all agencies that complete the report form in the State should commence using the new form at the same time. Unfortunately, many local agencies often prefer to continue using the old form. When new forms have been introduced, there have some who have attempted to use up the old ones before they start using the new ones. There are always a few police agencies that will resist change and continue to use the old form. It would create considerable havoc at the State data center if some agencies used non-scannable forms. It is imperative that no police or law enforcement agency that completes accident reports within the State is allowed to use a different form. Certainly, the benefits would decrease more than proportional to the number (and size) of agencies not using the same form. Moreover, substantial additional burdens would be imposed if the State data center personnel had to manually convert and key enter data for one or more cities or local municipalities that use their own unique accident report form.

While the implementation of a new accident report form is often a painful process, many States have recently introduced modifications of their State accident report forms. A review was undertaken of 51 State accident report forms in the National Highway Traffic Safety Administration's publication, "State Accident Report Form Catalog 1990." Of the 51 States, 3 States had revised their forms in 1990, and 7 States had revised their forms in 1989 or 1990. Between 1985 and 1987, inclusive, 17 States had revised their forms. Despite the date when the form was last revised, there may be a need to update it again. The National Highway Traffic Safety Administration (NHTSA) has established "Critical Automated Data Reporting Elements (CADRE) for Highway Safety Analysis." The CADRE elements are those elements that constitute a set of core data elements that "should be collected and automated by States to improve the analytic quality of police-reported accident data. They are "considered important for analysis, but are either not collected routinely by some States, are not of sufficient quality for analysis, or are not available for analysis on automated file." More than half of the States currently do not have provisions for the following on their forms:

- Most harmful event.
- Date of birth of occupants.
- Relation of first harmful event to roadway.
- First harmful event.
- Extent of vehicle deformity.
- Trapped/extracted.

In addition, very few forms currently have the additional supplemental truck and bus accident variables recommended by the National Governors' Association (NGA) and required for FHWA's SAFETYNET. A summary of key missing variables is presented below:

- 66 percent did not have vehicle configuration.

- 86 percent did not have cargo body type.
- 84 percent did not have gross vehicle weight.
- 94 percent did not have sequence of events.

In conclusion, it appears that many of the State accident report forms will again be revised in the near future. Thus, many States will have the opportunity to consider revising the formats of their forms to allow the use of form readers.

The public in Michigan thus far is not thrilled with reports where the majority of information is contained in "bubble" form, where for each variable on the accident report form, one of the applicable "bubbles" needs to be filled in by the police officer who completes the report. However, it should be possible to generate forms from the computerized (scanned) data that have text information in each of the fields. This would seem imperative in the not-too-distant future.

One potential area of concern was the effect that adverse weather would have on the form. Depending on the type and quality of the form reader, it may not be possible to successfully scan a form that gets wet due to rain or snow or other factors. The form must be allowed to dry before an attempt can be made to scan it. If a form was wet, smears may also develop if a pen was used to write the information on the form. If a pencil was used, the writing may have become dull from the water, and the software will also have difficulty interpreting the information on the form as well. Some form reader systems have the capability to display the image on a computer screen if the software is unable to interpret some of the data. These systems allow clerical personnel to make appropriate revisions and corrections. In Michigan, even damp forms that have no bleeding of ink from "bubble" to "bubble" do not appear to remain scannable after they have dried out thoroughly. Based on their initial experiences, Michigan indicated that most of the original forms that they receive from the State and local police agencies are scannable. One person expressed the opinion that the local police officers are possibly transposing information from a wet or damaged form onto another form before they send it to the State data center. If the form cannot be read at the State Data Center, then Michigan personnel will write (i.e., hand copy) the information onto a blank form and then scan that form.

Negative comments expressed by those involved with the Michigan report form included the following:

- The collision diagram and narrative were omitted from the 1992 form.

- Training sessions were hurriedly done.

- There was not enough input at the outset from all users of accident reports and accident data.

- The users were not prepared to decode the new data.

- Except for one city that used the UD-10 for 2 months prior to January 1, 1992, there was very little effort expended in pilot testing the new form.

- Human factors were not considered during the development of the form. This included the potential for police officers to evidently miss filling in all of the appropriate "bubbles," especially those in the middle of the form. One respondent indicated that the "bubbles in the center of the form tend to be left out" and that "officers still were not getting the hang of it as they are not only filling out the bubbles but also writing in the words."

One major disadvantage associated with the Michigan accident report form is that local police agencies had to find ways to retain a hard copy locally. The former one-sided report form that was used prior to January 1992 had a carbon copy for local use. Furthermore, additional documentation had to be available to accompany county reports for the public.

CHAPTER 4. COMPUTER TECHNOLOGY FOR AUTOMATING THE COLLECTION OF DATA AT THE ACCIDENT SCENE

PORTABLE COMPUTERS

While there are numerous types, portable computers were classified into laptops, notebooks, pen-based or clipboard computers, and palmtops for the purposes of this report. It should also be noted that the data on costs, sizes, weights and other parameters provided in the succeeding sections are current estimates and should be used as guides. With the computer market continually changing, portable computers are likely to be cheaper, more powerful, and smaller by next year or even next month.

Laptop Computers

Laptop computers are portable computers that can be programmed with task-specific applications to be taken into the field for data collection. There are a variety of laptops available in the computer market that range in processor type, weight, battery life, and cost. The list of laptop manufacturers is long and would include most of the desktop manufacturers.

The laptops range in weight from 7 to 20 lb (3.2 kg to 9.1 kg) and have a battery-life from 1 to 3 hours. The standard features found on a laptop are a keyboard, an 8-in by 6-in (203-mm by 152-mm) screen display, a 3.5-in (89-mm) floppy drive, and a serial and parallel port for interface with printers and other peripherals. Additional features that can be installed on a laptop include hard disks, which range in storage capacity from 20MB to 200MB, mouse input devices, and modems. Some laptops come equipped with an external expansion port that allows the portable to be connected to an expansion unit back in the office. Expansion units are docking stations that provide connections to external devices (e.g., hard disk drives, floppy disk drives). Some laptops can interface directly with an expansion unit by clicking the portable into the unit. Other laptops require additional connections for power, video, etc. Expansion units range in price from $1,000 to $1,500.

There is a wide range of system configurations available. The combination of features and the manufacturer will determine the price of the laptop, which could range from $2,000 to $8,000 for the 386-based models. With the introduction of the 386-based systems and the 486-based systems entering the market, the price of the 286-based laptops has dropped below $2,000.

Although the laptop is an effective tool, some drawbacks should be considered, such as:

- The size of the keyboard can be discouraging to users, especially inexperienced typists. Although they may contain the same number of keys, laptop keyboards are more compact than standard keyboards and require smaller hand movements when typing.

- Some of the heavier portables can be cumbersome to carry and operate outside of a vehicle.

Notebook Computers

Notebook computers, with a weight under 7 lb (3.2 kg), are a smaller version of a laptop. Notebooks differ from laptops in terms of available hard disk capacity and price. For notebook computers, the cost ranges from $1,800 to $5,000 for the 386-based models. As with the laptop, the system configuration and the manufacturer will determine the price of the notebook. The 286-based notebooks are now on the market for well under $1,500.

Notebook computers share the same advantages and disadvantages as the laptop computer. In general, the keyboards are, on the average, 1 in (25 mm) smaller than the laptop keyboards, which could cause frustrated typists on a laptop to be even more discouraged with a notebook. However, a user would find that the overall decrease in size compared to the laptop allows the user to carry the unit with less difficulty.

Pen-Based Computers

Pen-based computers, which have also been called clipboard computers, are handheld electronic tablets with character recognition features. This technology allows field personnel to perform onsite data collection with a pen and a computer rather than the manual method of pen and clipboard with paper forms. Pen input is possible with clipboard computers because of pattern recognition algorithms (i.e., optical character recognition software) that convert the marks made on the screen into recognizable characters. Alternatively, software can be developed that takes advantage of the pen's touch screen capability. So-called pop-up screens allow for data to be input without writing block letters.

Customized software can be developed to accommodate the user's specific data entry tasks. The programs can range from fundamental, which provides fields for the user to enter the data, to sophisticated, which performs online error-checks and provides menus of the possible responses for data items. The more complex software removes the reliance of the pen-based computer on optical character recognition software. The user can select items from a menu or characters from a keyboard displayed on the screen by touching the screen with the pen. This reduces the need to train the OCR software to recognize the user's handwriting.

Currently, the weight of these computers ranges from 3 to 5 lb (1.4 to 2.3 kg) and the average dimensions are 9 in by 13 in (229 mm by 330 mm), which is the size of a standard metallic clipboard. The displays are 8.5-in by 11-in (216-mm by 279-mm) LCD screens. Clipboard computers operate with removable RAM cards instead of hard disks. The unit cost of a pen-based clipboard computer ranges from $1,500 to $7,000. These computers are available with internal modems and can be interfaced with printers, keyboards, bar-code readers, spread spectrum radios, GPS receivers (eventually), and other peripherals.

More and more pen-based computer products are being introduced into the market. Figure 9 shows the Grid System's GRiDPAD that is currently being used and evaluated in the field by police agencies in several cities, including West Palm Beach (FL), Mobile (AL), Alexandria (VA), Arlington (VA), and San Jose (CA). Figure 10 shows a smaller version called a PALMPAD recently introduced by Grid and the RAM card. The current manufacturers of clipboard computers include, but are not limited to, the following:

NCR Corporation.
Grid Systems.
Data Entry Systems.
MicroSlate.
Momenta Corporation.
Samsung.
Comdex.

As can be done with laptops and notebooks, this technology reduces in-office data entry time by allowing the user to record the data onsite, and to electronically transfer the information to another storage device in the office.

Figure 9. A pen-based clipboard computer.

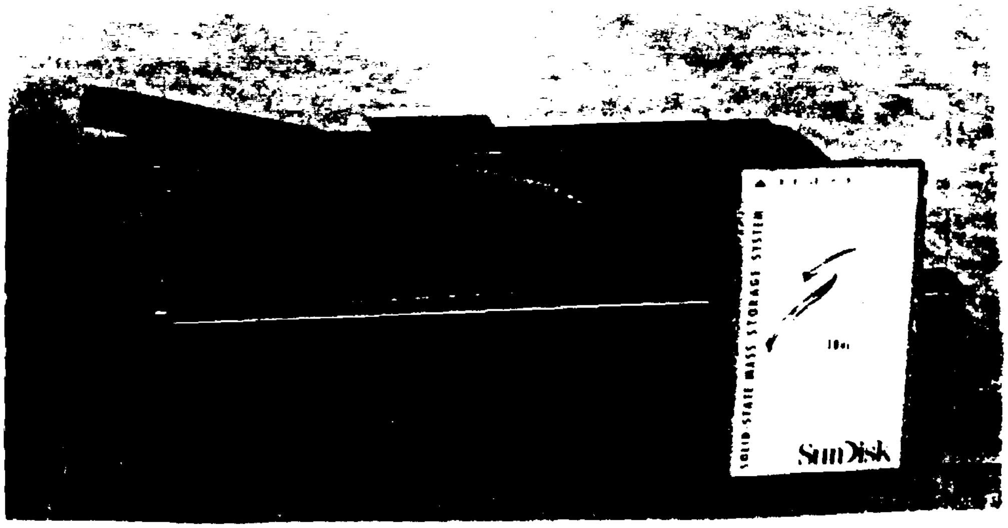


Figure 10. A RAM card and a smaller version of a pen-based clipboard computer.

New input technologies will soon be abounding in the computer market. Current research is being done with touch screen input. The existing pen-based technology will soon be available with notebook computers with detachable keyboards. Manufacturers that are readying their pen-based notebook computers for the market include, but are not limited to the following:

- NCR Corporation.
- Momenta Corporation.
- Tusk, Inc.

Palmtop Computers

Palmtop computers can be divided into two categories: hand-held computers and hand-held data entry terminals. Both are powerful for task-specific applications, although not as powerful as the larger portables. They weigh under 1 lb (0.45 kg) and most cost under $1,000. The hand-held data entry terminal is designed by the manufacturers for a specific data entry task and are equipped with removable storage devices or a data link for transferring the information to a larger computer in the office. They have very small keypads for one-finger data entry and screens that display only a few lines of data.

The hand-held computer is more flexible than the data entry terminal. These computers support DOS applications and depending on the storage capacity, can be loaded with more than one application. They are similar to the terminals in that they have very small keypads and displays.

The following are some of the current manufacturers and applications of the hand-held computer. This list is not all-inclusive.

- Hewlett Packard has released a palmtop with Lotus 1-2-3 built into the ROM. At a cost of $700, this computer offers a 16 by 40 character display, a keypad, and 512K RAM.

- Sharp Electronics Corp. will be releasing the PC-3000. This system was designed for field personnel who need DOS applications.

- Psion has released a semi-DOS compatible system with 256K RAM.

The Palmtop could be a useful tool for single data collection field tasks. However, tasks that require input on large data forms could not be accommodated by this type of device. The size of the keypad, although handy for one finger typists, can be cumbersome to use. The size of the screen display is also a problem. Due to its inherent limitations, it has limited application for accident data collection. Consequently, it is not addressed throughout the remainder of this report

APPLICATION OF PORTABLE COMPUTERS TO THE ACCIDENT DATA COLLECTION PROCESS

Existing Applications by State and Local Police Agencies

Several police agencies are now using microcomputers as an aid in the preparation of a variety of police report forms. Although there are likely to be many other police departments throughout the United States that are using microcomputers to manually enter data to create report forms or information data bases, several notable applications were identified as part of this research. These include the following:

- City of St. Petersburg, Florida, Police Department.

- City of Clearwater, Florida, Police Department.

- City of Santa Cruz, California, Police Department.

- California Highway Patrol's Automated State Traffic Officer Reporting System (ASTORS).

- City of West Palm Beach, Florida, Police Department.

- City of San Jose, California, Police Department.

Each of these applications are discussed separately in the following paragraphs.

St. Petersburg, Florida. The St. Petersburg Police Department uses portable computers for crime incident reporting only (homicide, burglary, etc.), not for accident data collection. Currently, they are now using the Tandy 102 computer, which is a variation of a notebook and a nonpen-based clipboard and is shown in figure 11. As far as crime reporting goes, they have found the computers to be very reliable. Officer acceptance has been very positive, and training has not been a problem.

Figure 11. The Tandy Model 102 computer used by the St. Petersburg Police Department.

The St. Petersburg Police Department indicated that the ability to analyze crime data afterwards is one of the major benefits of using the clipboard computers. The time savings in collecting crime data was judged to be of lower importance. The City hopes to use computers for accident data collection in the future, but has run into the following obstacles:

The Florida statewide Accident Report form was seen as difficult to convert to their computer system. The Tandy Model 100 is a standard keyboard-based computer.

It was perceived that the software that could be used to enter the data from the statewide accident report form on Tandy Model 100 would be unwieldy to use.

The DOT in Tallahassee will currently only accept its standard accident report form and has not been willing to accept data in another format or on electronic media.

The current St. Petersburg accident reporting practice requires police officers to provide information to those involved in the accident. Since the officers currently do not have access to printers in their vehicles, this would require the officer to fill out the information once on computer and then a second time on paper.

Clearwater, Florida. The city of Clearwater, Florida, received a grant from the National Highway Traffic Safety Administration (NHTSA) to implement a computer-based accident data collection system. The system has been up and running for about over 18 months. The Clearwater Police Department has 225 Toshiba Model 120 laptop computers, one for every officer. The Toshiba is a keyboard-based computer with two 3.5-in (89-mm) disk drives and battery power. They designed and created a special mounting hardware to place the computer in the police vehicle, making it accessible and easy to use. This is illustrated in figure 12.

Figure 12. Clearwater Police Department's mounting harness with and without the Toshiba computer.

Software, which is based on dBase III, was developed by Advance Systems Design (ASD) of Tallahassee and written specifically for the city of Clearwater. The software can generate a report form that has been approved by the Florida DOT in Tallahassee. More information is now gathered with the computer than with the statewide traffic accident report form.

Currently, police officers turn in 3.5-in (89-mm) diskettes at the end of their shifts. The accident information is then copied onto another personal computer. The report is then reviewed on the screen by the traffic officer for accuracy and completeness. The software has some built-in error checks. However, since it is not foolproof, manual review is necessary. A hard copy of the report is then printed and sent, along with a diskette, to DOT in Tallahassee. As with St. Petersburg, the DOT currently requires hard copies of the reports. The DOT is required to maintain a microfilm library of accident reports, as is the Clearwater Police Department, so hard copies are necessary. It is hoped that this will be eliminated in the near future and that all records will be computer-based. The DOT in Tallahassee then checks the traffic accident reports and returns reports that are unsatisfactory.

The city of Clearwater uses the accident data not just for traffic safety. Some information (names, violations, other occupants in vehicle) is distributed to other departments. The following example was provided to illustrate the use of accident information: A suspect in a crime had claimed not to know another suspect. A search of accident records was done and it was discovered that the two had been in the same car in a recent traffic accident. The new system has allowed the city to do much more data analysis than was previously done. Before the system was implemented, analyses were performed manually and were very cumbersome. Now, much more efficient analyses are performed.

According to the Clearwater Police Department, a major failing with previous computer systems tested in Florida was that the officer could not exit the program if he got an emergency call while filling out an accident report. Built-in error checks would prevent an officer from exiting a partially completed form. Consequently, the officer would have to turn the computer off and lose data. The Toshiba computers have a feature that allows the officer to simply turn the system off without losing the data. Because all data are saved, the officer can complete the report days later.

Generally, officer acceptance has been very positive. There are a few who "dislike" the computers, but these are "the guys who think ball point pens are a passing fad." Most officers had no trouble adapting to the system. Some officers will not turn them over for maintenance unless they are given a replacement. There was one unexpected development. Many officers have begun using computers for generating other incident reports. Many have developed their own report forms, and now the department is trying to standardize these forms so that all officers can use them. They have had no problems with keyboard-based systems. The reliability of the 225 Toshiba computers has been "phenomenal." The only problems have been with a few batteries and a couple of screens. The computers were purchased solely for this project.

In Clearwater, the use of computers has not reduced data collection time in the field. The big benefit has been in the elimination of the data entry stage and in improved data. There had been a substantial data entry backlog before the system was implemented. Illegible reports were also a big problem. Now the quality of the final reports is far superior, and there has been a reduction in data entry errors.

All training was done inhouse. In general, very little time was required. There were a few problems. The police officers had to be taught to perform data entry in precise order. For example, often all people involved in the accident would be entered as being in the same vehicle. After all officers were taken through the correct procedure by an instructor, the problem was solved.

The system presently does not have graphics capability. Officers must prepare sketches of the accident diagram and/or vehicle damage on paper and submit them with the disk. The sketch is kept with the hard copy at this point. ASD is now developing a basic graphics package that they hope will be online in 6 to 8 months. It will have basic functions similar to Mac-Draw and PC-Draw. It will be menu driven and will allow the officer to move and rotate preprogrammed icons of vehicles, posts, bushes, etc. They hope to have the 40 most common intersection types preprogrammed so the officer does not have to draw them. The police department is also in the process of adding special invehicle cradles in which the computer is set to charge automatically. Their ultimate goal is to use computers as mobile data transmitters/receivers. The city had issued a "request for proposals" for the development of a system in which the computers would also function as MDT's, but their radio frequency (800 MHz) is creating problems with the transmission of data. Consequently, implementation of this system is at least 3 years away.

Additional improvements that are also being developed include the following:

- Increasing speed of input.
- Allowing information to be carried over from one report/citation to another.
- Pre-filling some data fields.

The computers are not currently used for issuing citations because the police cruisers do not have printers. The city has no plans to use the computers to issue citations in the immediate future. However, the computers are used for other traffic violation reports.

Santa Cruz, California. Originally, the police officers would record their reports on audiotape and then transcribers would type the reports. However, they were finding that due to higher priority assignments (i.e., homicide investigations, etc.), it was taking a relatively long time (2 to 4 weeks) for the tapes to be transcribed. Utilizing funds from a grant from the California Office of Traffic Safety, the city of Santa Cruz implemented a pilot program that featured the use of Toshiba laptop computers. The fact that the city had a dynamic computer "jock" on the police force greatly aided the shaping of the program and the development of the software. This individual developed a computer program, written in BASIC, for an officer to enter the data for a motor vehicle traffic accident. The software can also be used to generate a traffic collision report that looks approximately the same as the standard CHP 555 available from the California Highway Patrol. The program was hampered slightly when the individual left the city of Santa Cruz to join another city's police force.

The city of Santa Cruz had requested that all patrol vehicles be eligible for the laptop computers. However, due to a restriction with the OTS grant, only "traffic vehicles" were eligible. This meant that only the motorcycle units were eligible. The laptops can be affixed via velcro in the luggage compartment of the motorcycle. Figure 13 illustrates how the laptop computer is mounted on the motorcycle. Although they have encountered communication problems, the system was designed to provide two-way data communication over the radio frequency band. A mobile data terminal device is used to interface the laptop computer with the police radio. As shown in figure 14, it is located just above the instrument panel. The city has at least two officers who have become very proficient at entering the information "real time" at the scene of the accident. While several others are still mastering the skill of entering the data in the field, they have become adept at entering the information at their desks in the police station. Using a blank form 555, they record information in a very rough draft format on the form. Upon returning from the field, they enter the data and create the computer-generated report form. The average time lag between when the accident has occurred and when it is filed has decreased to 5 days. Patrol officers assigned to police cruisers have shown an increased interest in the use of laptop computers, especially in the use of the traffic collision report software. If and when funding becomes available, the City plans to purchase and install additional laptops for the sergeants' vehicles and possibly for some patrol vehicles in the future.

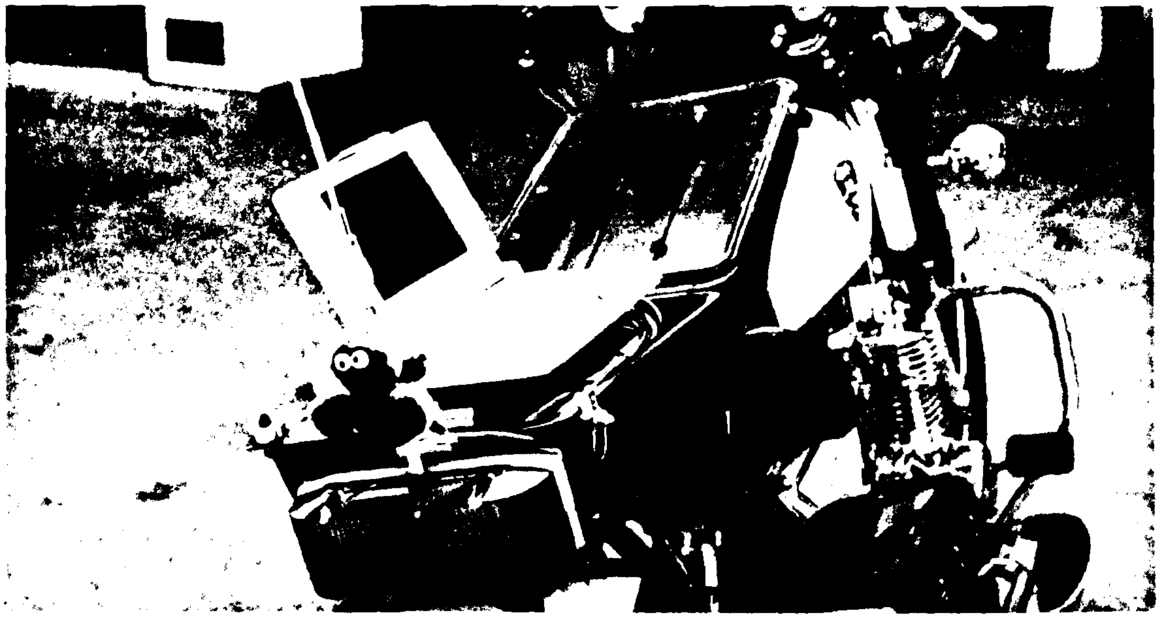


Figure 13. Santa Cruz Police Department's motorcycle-mounted laptop computer system.

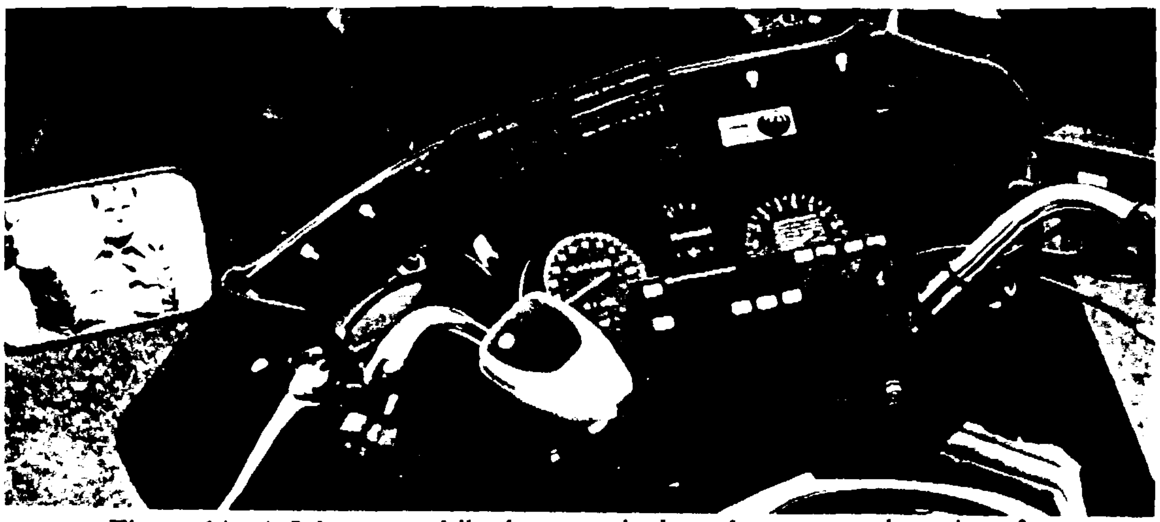


Figure 14. A Johnson mobile data terminal on the motorcycle to interface with a Motorola radio for digital two-way communication link.

California Highway Patrol's ASTORS. The California Highway Patrol (CHP) is currently conducting a pilot study on an Automated State Traffic Officer Reporting System (ASTORS) that involves the use of laptops and computer software that generates the traffic collision form 555. Four CHP areas and two sheriff departments are currently participating in pilot tests under the sponsorship of the CHP. Depending on the results of those evaluations, the CHP may offer the software to all cities and municipalities in California and to all divisions and areas of the CHP. However, as noted by the CHP, their mainframe computer-based statewide Integrated Traffic Records System (SWITRS) currently does not have the capability to accept electronically transmitted data. Based on preliminary information on "time to complete" from CHP's Laptop Study, the average total writing time for an investigation is 152 min, and the average total writing time for a report is 91 min.

West Palm Beach, Florida. The West Palm Beach Police Department is in the process of converting to the use of Grid Systems Corporation's GRiDPAD portable computers as a pilot demonstration project. While the City felt there were probably a half-dozen systems in the marketplace that could do the same job, a pen-based system was preferred. Because it was their belief that police officers do not like keyboard-based computers and find them cumbersome, they felt it would be easier for officers to learn to use a pen-based computer. They identified the following as the major selling points for selecting the GRiDPAD:

- Pen-based.
- Possibility of integration with other technologies such as a Global Positioning System (GPS), which is described later.
- Potential to incorporate a magnetic stripe reader and be used for traffic citations as well.
- Good graphics capability.
- Company reputation.

The current problems that they have experienced with the Florida statewide accident report form include the following:

- The form takes about an hour to fill out in the field.
- Data-entry - currently there is about a 2-month backlog.
- Incomplete forms - officers often leave fields blank.

They set aside $40,000 in money seized from drug dealers to buy 10 GRiDPAD's and the accident report form software from UCS of Fort Lauderdale. The goals for a new system that features the use of GRiDPAD's are:

- Reduce data collection time by about 40 percent, from 1 h to 35 or 40 min.

- Eliminate data entry stage.

- Eliminate incomplete forms by the use of error checks and mandatory fields. Also cut down on errors through built-in error checks.

The current process requires each accident report form to be reviewed by a superior officer within 24 hours of submission. Even with GRiDPAD's, they will keep this step. They plan for every officer to have a GRiDPAD, and while they expect fewer mistakes, they still expect that some officers will record information incorrectly. Therefore, manual error checks will be retained. The department plans to download the accident data at the end of each shift or each day to their mainframe using a PC interface. Information will then be reviewed and approved. The department hopes to be able to send data via modem to Tallahassee directly, but this arrangement has not been finalized. They may have to generate hard copies at first. Because this is an "ice-breaker," they think that the Florida DOT will begin to accept electronically transmitted traffic accident data directly. They currently send accident data every 2 months.

The city's police department already does a considerable amount of inhouse data analysis. They anticipate that GRiDPAD's will not give them any new capabilities, although they plan to eventually use the computers for traffic citations. They want to make sure the system works before buying printers. The city's ultimate goal is real-time voice and data transmission by radio, which is not expected for several years. At the time of this report, they were currently in the evaluation stage.

San Jose, California. The city of San Jose, California, Police Department is now entering phase 2 of a multiphase evaluation project. For phase 1, as part of a pilot test, they used pen-based clipboard computers to prepare crime and property reports for citizens who walked into one police station. On the basis of the pilot test, they made several revisions to the computer data entry screens. For phase 2, which is scheduled to begin on February 1, 1993, they plan to go out in the field and test use the computers. They currently do not have software to generate an accident report. UCS of Fort Lauderdale has offered to sell them the software at $995 per unit license. The city indicated that they would like to obtain the CHP software (currently being fieldtested, modified, and refined) and then modify it so it can work with their computer hardware, including the Grid Systems Corporation's pen-based clipboard portable computer called the GRiDPAD. They indicated that all software for GRiDPAD's were programmed in C language. It should also be pointed out that the San Jose Traffic Collision Report form differs from the CHP Traffic Collision Form (form 555).

As part of their phase 2 study, which is scheduled to be concluded in June 1993, they plan to evaluate the following four different technologies/methods:

- Pen-based, clipboard computers with external keyboards.

- Notebook/laptop computers.

- The existing process/procedures.

Computer-Assisted Report-in (CAR) Entry in which a transcriber at the police headquarters will interact with a police officer in the field using a canned paragraph interview form. (St. Louis County, Missouri has had success using this method.)

The San Jose Police Department intends to obtain a representative sample of 16 volunteers and rotate them through all 4 technologies. They will put the equipment in a specific car and assign that car to specific officers. They will evaluate the technologies in terms of:

Time spent writing reports.

Training time.

Durability.

Ease of use/user acceptance.

Timeliness - time when report becomes available online.

Personnel requirements.

The San Jose Police Department also is currently evaluating pen-based clipboard computers with external keyboards and laptop computers as MDT's in their police vehicles and to compare them to their existing Motorola MDT's, which were purchased in 1976. Figure 15 depicts one of their MDT's. One of the issues that they are attempting to resolve is whether the MDT's should be replaced with laptops. Figure 16 illustrates how a pen-based clipboard computer with a detachable keyboard might appear in a police vehicle.

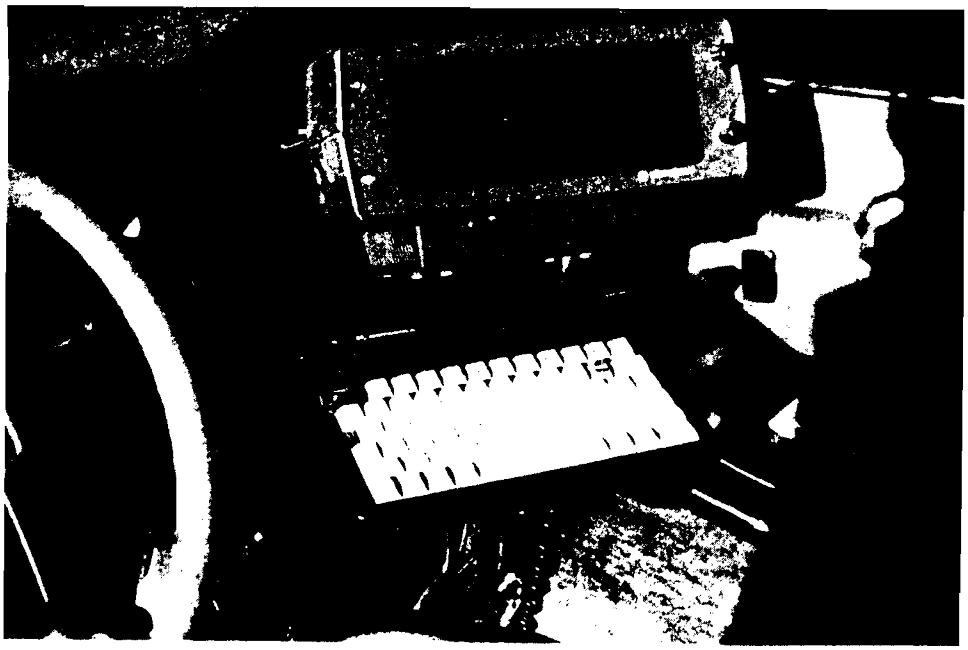


Figure 15. San Jose Police Department's Motorola mobile data terminal.

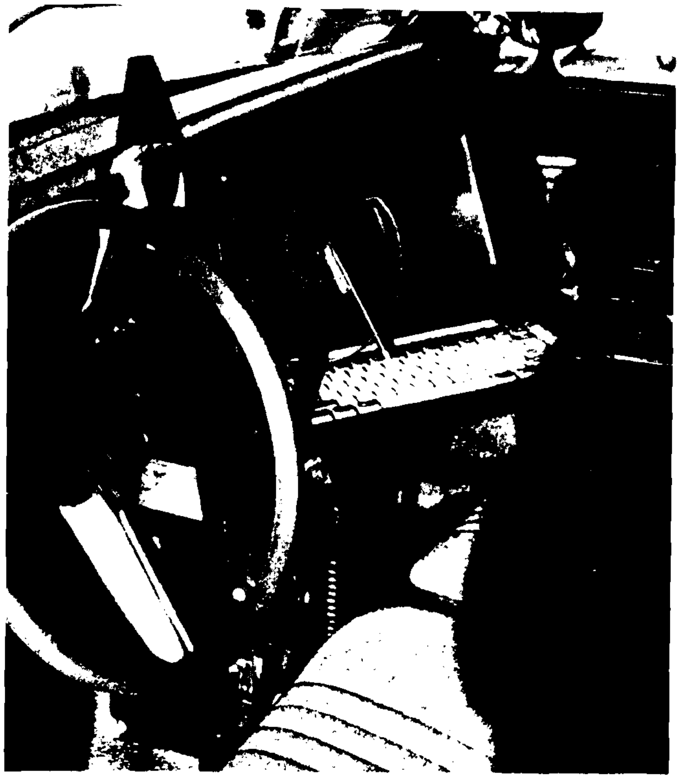


Figure 16. Illustration of a pen-based clipboard computer with external keyboard in a police vehicle.

Implementation Scenarios

Portable computers can be applied to the task of accident data collection in several methods:

1. A straight implementation of the computer in the field for the purpose of accident data collection only.

2. An implementation of the computer for the purpose of automating the collection and preparation of all police reports (e.g., incident, crime, etc.).

3. The above implementation of the computer for all police reports and to serve as a mobile data terminal for a computer-aided dispatch (CAD) system.

4. An implementation of the computer with integrated identification technologies for collecting encoded information from magnetic stripes and/or bar codes.

5. An implementation of the computer with an integrated location technology.

6. An implementation of the computer with integrated readers for identification technology and an integrated location technology.

There are several issues that need to be addressed in order to determine the feasibility of each of the above methods:

Battery life.

- Durability.
- Memory and storage requirements.

The battery life of a portable computer ranges from 1.5 to 4 hours. Both the type of battery and the configuration of the computer play a role in the actual run-down time of the battery. The latest power-saving computer processor chip is the SL. It provides power management and clock stopping features to the portable. This will allow for the power to be shut down to the memory, disks, screen, and peripherals of the portable when they are not in use. In considering screen types, color displays should not be considered because of the excess drain on the battery. Hard disks also draw heavily from the battery. The selection of RAM cards over hard disks will be discussed for this reason. The more powerful the portable, the greater the power drain on the battery, and the more powerful the battery, the heavier the portable. Two options to consider when selecting a portable for power vs. battery life and portability is the use of replaceable batteries and invehicle rechargers.

The durability of a computer is a major consideration when selecting a portable for use in accident data collection. Most portables can withstand a high temperature range for field use. The damages that can occur from misuse, such as dropping, require the consideration of insurance coverage and maintenance contracts.

The storage requirements are dependent on the implementation of the portable. If only one accident form will be implemented on the portable, then the storage requirements will obviously be less than the case where all police report forms will be supported on the portable computer. The storage requirements for data collection during one officer's shift, using a typical accident record, would average 60 KB per 100 records, not including the narratives. The memory requirements are dependent on the largest application to be used on the portable.

When considering storage capabilities, the hard disk and RAM cards are the two options. Both devices can be used as removable storage components. The RAM card is preferred over the hard disk because the RAM card does not have any moveable parts, requires less power from the battery, and weighs much less than a hard disk. External hard disks with separate power supplies can be interfaced to portables, but this will add an extra device to carry and will not eliminate the durability problem of hard disks with moveable parts. If RAM cards are selected, however, the computer must support this device and comply with PCMCIA (personal computer memory card international association) standards. Currently, not all portable computers provide this feature.

The issues of battery life and durability are the same for clipboards as for laptop/notebook computers. However, the issues of memory and storage requirements are different. The clipboard computers will have to be operated with RAM cards instead of hard disks. This difference can be considered a plus because of the durability of RAM cards with no moveable parts.

An additional issue to be addressed in selecting a computer is the processor type (e.g., 286, 386, 486). The three major concerns are power, cost, and availability (i.e, manufacturer support, replacement parts, etc.). The 486 is a much more powerful machine than the 386 and 286, and the availability is greater because it is the newer model. However, the cost of the 486 is going to be higher than the first two types. When considering all three factors, the 486 is the preferred processor because of the constant changes in the computer market. The 286 computers, although much cheaper, are almost obsolete. In another year, when a new more advanced processor type is available, the same may be true of the 386.

Operating Systems

The standard configuration for laptop/notebook computer systems is a DOS operating system with keyboard input. Recently, however, a notebook computer with a keyboard/pen input configuration has emerged onto the market. This new input combination for the notebook is available under several pen operating environments. Two of the more prominent are:

- MS-DOS Windows operating environment with PenWindows.
- PenPoint operating environment developed by Go Corporation.

PenWindows requires a DOS Windows environment to operate on a notebook computer. An advantage to this system is the DOS compatibility, which allows the use of other DOS Windows applications and the option of keyboard or pen input. A disadvantage is the additional memory and storage requirements necessary for driving the Windows environment.

The PenPoint operating system is new to the notebook computer market. This system is not compatible with DOS, meaning all applications that run on the notebook must be developed for a PenPoint environment. Initially, this could be a substantial drawback to users who rely on their DOS-based applications. However, the users that need a notebook computer for pen input only may be pleased with the ease and responsiveness of the PenPoint environment. Penpoint also supports keyboard input.

The major concern with all pen operating systems is the capability of the optical character recognition software that interprets the pen marks on the screen. With the latest advancement of the pen operating systems, the user can train the clipboard to recognize his/her handwriting. This process is easier for some than others, depending on the user's handwriting. Also, there is the problem of the number of users that need to train a computer. Most operating systems also provide a keyboard display for screen typing with the pen and menus for selecting operations with the pen. Thus, it is possible to use a pen-based computer utilizing the optical character recognition (OCR) software.

Implementation Costs

The computer alone will range from $2,000 to $8,000 for a laptop and $1,800 to $5,000 for a notebook. A clipboard computer will range from $3,000 to $6,000. A portable printer will range from $300 to $700.

If the computer is used also as a mobile data terminal that will function within a computer-aided dispatch (CAD) system, then a docking station in the vehicle is required to allow digital data communication link with the central dispatcher.

Cost for additional peripheral equipment is as follows:

- A wand-type bar-code reader ranges in price from $400 to $600. A scanner type reader will cost from $700 to $1300.
- The average price for a mag-stripe reader is $300.
- The cost of smart card readers is approximately $100 to $200.
- The cost of GPS receivers is approximately $500.

Software Requirements

Before developing the software for safety data collection, the required level of sophistication needs to be established. Issues to be resolved are:

- Will the software be a direct automation of the form that will allow the user to mark any input into the fields?
- Will the software be a direct automation of the form with field validation that will allow the user to mark only legitimate responses in the fields?
- Will the software be an expert automation of the form that will validate all responses and direct the user through the form based on previous responses?

In addition to the level of sophistication, the method of data input will affect the software development:

- Implementation method one requires only keyboard input. No additional programming is necessary.
- Implementation method two and four require input from ID technologies. Additional programming is required to accept data from the selected ID input devices.
- Implementation method five requires no additional input for the docking station.

The level of difficulty and cost for the development of the software ranges from low to high for the level of sophistication. If all forms are to be implemented, then the additional cost for the development of software for each form is incurred. The success of any of the methods of implementation relies greatly on the software. The degree of the software's ease-of-use directly affects the amount of training required and the user's acceptance of the system. As the implementation process progresses, developers should be prepared for maintenance and upgrade requirements on the software.

The software requirements for clipboards are the same as for laptop/notebooks, except for the difference in data input, specifically the pen over the keyboard. However, keyboard input can be considered in addition to pen input.

Implementation Steps

To automate the accident data collection process in the field, the following steps will have to be considered by each individual site:

1. Determine the most feasible method of implementation (hardware configuration).

2. Determine the type of software required for the task.

3. Develop the implementation scheme. (Purchase/assemble the hardware; develop and test the software.)

4. Demonstrate the complete package and train a sample of the users.

5. Pilot test the product in the field and correct any observed problems.

6. Develop and implement a training plan for all users.

7. Develop and implement a maintenance plan for the equipment and software.

8. Perform a full implementation in the field.

Anticipated Benefits

With respect to the collection of accident data and the preparation of accident reports, the use of computers by law enforcement officers at the scene of the accident can reduce the problems associated with legibility of the reports. The use of computers can reduce the amount of missing or inaccurate data if sufficient error traps can be designed into the system. For example, the data input program can be structured so as to prompt for missing fields or not allow the user to exit until entries have been made for all fields. Although it has not yet been fully and adequately demonstrated, at least one evaluation study indicates that the use of computers to prepare traffic accident reports can actually reduce the amount of time it takes for a police officer to complete a report.

It is also possible to design the "smart" software that requests additional data that is appropriate for that specific accident. If a particular variable on the form is not appropriate, then a prompt for that information will not appear during the input stream. This would possibly allow for the recording of additional data that is currently not gathered on the form. Consider a single-vehicle, run-off-the-road, hit fixed object accident. Currently, many State forms do not require information on where the fixed object is relative to the edge of the travel way. It would be relatively simple for the software to be tailored to ask for input on the type of fixed object and the lateral displacement to the fixed object if the accident is a run-off-road type. Moreover, by specifying that only one vehicle was involved, the software would not ask for inputs on the driver's name, address, date of birth, etc. for vehicle number 2.

Compared to the revised report form and form reader application, the use of computers in the field has far greater potential for additional improvements in the future. The next chapter describes identification technologies such as magnetic stripe and bar codes. If a State begins to issue driver's licenses or vehicle registration cards with magnetic stripes, then the computers can be adapted to extract and capture the driver and/or vehicle information from the magnetic stripe. This would significantly reduce the time required for the police officer to manually write the driver's license numbers, names, addresses, dates of birth, etc. of all drivers involved or to manually write the vehicle make, model, year, body type, and vehicle identification number of all vehicles involved. Police officers could not reap the benefits (e.g., time savings, improved quality of the data, etc.) of these identification technologies if they are required to fill-in-the-circles on a special accident report form. However, they could easily take full advantage of the identification technologies to reduce the demands on their time at an accident site if they had computers.

Limitations/Disadvantages

There are potential problems to consider with the implementation of laptop, notebook, or pen-based clipboard computers in the field for accident data collection.

- Police officers who are currently using computers in the field have indicated a high potential for damage due to its portability (e.g., dropping, left on hood of car, etc.) and anticipate misuse (e.g., "off-the-shelf" software games).

- Some police officers may have an aversion to using a computer and many may first experience problems with typing on the laptop/notebook keyboards.

- Laptop and notebook computers may be cumbersome to use outside of the vehicle.

- The officer may have a problem with entering ("straight" typing) the narrative section.

- Laptop and notebook computers currently do not facilitate the creation of an accident diagram. A graphical interface will have to be available for the drawing of the sketch.

In addition to the laptop/notebook disadvantages, the pen-based technology has one other major limitation. The OCR software is still in its infancy in terms of development, therefore, the officer's handwriting can still present problems. Although, a user can train the software to recognize his handwriting, the amount of effort required for this process depends on the clarity of the individual's handwriting. Also, if the computer has multiple users, each user will have to train the software for his handwriting. For this to be feasible, the operating system will have to allow for multiple handwriting files. As discussed previously, the current problem with OCR software can be eliminated by the development of a very sophisticated software data collection program that provides selection menus and keyboard displays for the narratives.

RELATIVE COMPARISON OF COMPUTER TECHNOLOGY FOR ACCIDENT DATA COLLECTION

First, it should be noted that there are benefits that would be accrued regardless of the type of portable computer implemented. The use of laptop, notebook, or pen-based clipboard computers by police officers at the accident scene offers the following advantages:

- The immediate storage of data onsite will reduce or even eliminate data input time in the office.

- A data entry program with error-check features will reduce data entry errors onsite, and the use of a portable computer at the accident scene will remove the problem that a data entry clerk might have interpreting police officers' handwritten reports.

- The interface capabilities of a portable computer will permit the use of other data collection devices, such as bar-code and magnetic stripe readers, digital cameras, etc. All three types of portable computers can be configured to electronically capture data on magnetic stripes or bar codes. This would further reduce data entry time and errors.

- Some police officers that are currently using portable computers in the field have found that the computers can increase their productivity/efficiency.

- A portable computer can be used for multiple data collection activities.

There are many relative advantages to implementing a laptop vs. a notebook vs. a pen-based computer with optical character recognition software in the field for the purpose of accident reporting and collecting accident data. Laptops and notebooks share many common features, including integrated keyboards. The major difference is in weight. The advantage of the notebook over the laptop is the weight. Notebooks are lighter and more portable. In addition, notebook computers are available with the pen-based technology. Keeping these differences in mind, laptop and notebook computers have the following advantages over pen-based clipboard computers with OCR:

- The technology is widely used and readily accepted.

- Laptop/notebook computers are readily available in commercial markets.

Compared to laptops and notebooks, pen-based computer technology offers the following advantages:

- Some officers can more efficiently record accident data at the scene by using a pen instead of a keyboard.
- Pen-based computers allow for the sketching of an accident diagram.
- The officers are not required to type on a keyboard. Handwriting the form with a computer pen is similar to the current process.
- The use of pen-based computers should require considerably less training because of the similarity to the original task of paper forms.

Th
lea
ot
co
ha
id
m
us

II

T

N

N

CHAPTER 5. TECHNOLOGIES FOR AUTOMATING THE COLLECTION OF DRIVER AND VEHICLE IDENTIFICATION DATA

The use of bar codes and magnetic stripes have become quite common in the United States. At least one State has been issuing driver's licenses with magnetic stripes since early 1991. Several other States are in the process of converting to driver's licenses with magnetic stripes and/or bar codes. Several vehicle manufacturers have begun to use bar codes to track inventory. If drivers had magnetic stripes encoded with their driver identification information and/or vehicle identification information, then a police officer could obtain driver and/or vehicle information more quickly and accurately at the scene of an accident. This type of technology could also be used to facilitate the identification of problem drivers and vehicles at the scene of the accident.

IDENTIFICATION TECHNOLOGIES

The identification technologies that were evaluated included:

- Magnetic stripe systems.
- Bar coding systems.
- "Smart" cards with radio frequency chips.

Magnetic Stripe Technologies

Magnetic stripe systems use the magnetic field of an encoding head to record magnetic flux reversals. This information is placed onto a layer of magnetic material similar to that on an audio or video tape. The layer, called a magnetic stripe, is generally attached to the front or back of a paper or plastic card. A decoder reads the flux reversals and translates them into letters and numbers for processing by a computer.

Compared to printed data, the magnetic stripe allows the storage of large amounts of data in a small area. A single magnetic stripe can have several tracks of recorded data. Information on a magnetic stripe card can be rewritten and updated. Because it requires sophisticated equipment to produce mass quantities of cards, the magnetic stripe is popular for high-security applications.

Magnetic stripe standards have been developed in two major segments: physical standards and application standards. Physical standards define recording track locations, encoding methods, data densities, and magnetic recording qualities. Application standards deal with data content and format for different market usage. Currently, magnetic stripe standards only exist for financial applications. Additional standards and guidelines for magnetic stripe media and equipment, and for nonfinancial applications, are in the draft stage. Presently, adherence to standards is mandatory if the card will be used in the financial system, but only voluntary for other applications.

The best known applications of magnetic stripe technology are on credit and debit cards for use in automatic teller machines (ATM's) and point-of-sale terminals. Magnetic stripes are also used for access control to secured buildings and other facilities. Further uses are for time and attendance systems, inventory tracking, personnel identification, amusement parks and games, manufacturing process control, transit fare collection, and sales.

The magnetic stripe actually contains three separate tracks that are available to store encoded information. In a customized application, such as a driver's license and vehicle registration card, each track could store a different piece of information. Each track can store approximately 40 bytes of data. Thus, other information, in addition to a driver's license number or vehicle identification number, could be stored on a magnetic stripe.

Bar Coding Technologies

Bar codes consist of a series of black and white bars of varying thicknesses and patterns to represent alphabetic characters or numbers. An optical scanner emits a beam of light and records the pulsated reflection that occurs when light bounces off the black and white bands. In turn, the scanner digitizes the pulsated reflection, converting the light into electrical binary digits, the same system of 1's and 0's that provides the basis for a computer's operation. Bar coding and bar-code applications have soared in the past 10 years. Principal applications include item tracking, inventory control, monitoring work-in-progress, assembly verification, order entry, document tracking, receiving, and point-of-sale operations.

There are currently a variety of bar-code standards. A number of major industry associations, in fields ranging from automobiles to pharmaceuticals, have adopted one of several existing bar-code symbologies as their standard. Five bar-code symbologies are commonly used in American industry:

- Code 39.
- Universal Product Code.
- Code 128.
- Code 93.
- Interleaved 2 of 5.

Code 39, which is very popular in industrial, medical, and government applications, is a bidirectional, alphanumeric symbology with self-checking properties that offers a variable length and a high degree of data security. The Universal Product Code is extensively used in retailing. Code 128 and Code 93 are alphanumeric codes that offer high density and high data security. Interleaved 2 of 5 is a self-checking, numeric symbology adopted by the Uniform Code Council for use on outer shipping containers. It is also used for identification of photofinishing envelopes, in heavy industrial applications, and for warehouse inventory handling.

Bar-code symbologies differ in terms of size. The space required for each of these symbologies is linear. For example, a code containing 10 characters would require approximately one-half the space of a code containing 20 characters. It should also be noted that Code 39 only supports 43 different characters and numbers, whereas Code 128 and Code 93 support the entire ASCII character set (i.e., 128 characters and numbers). Table 3 provides estimates of the amount of space needed for the most common bar-code symbologies that support alphanumeric data.

Table 3. Length of bar codes for common symbology.

Symbology	20 Numeric Digits	20 Characters
Code 128	1 1/2 in (38 mm)	2 1/2 in (64 mm)
Code 93	2 1/8 in (54 mm)	2 1/4 in (57 mm)
Code 39	3 1/2 in (89 mm)	3 1/2 in (89 mm)

"Smart" Cards with Radio Frequency Chips

"Smart" cards are credit card-sized devices that contain microelectronics that can store and transmit information. Unlike bar-code and magnetic stripe technologies, smart cards can store most, if not all, required driver and vehicle information. A smart card can store approximately 3,000 bytes of information. Smart cards could be used to store vehicle status and operation data along with the vehicle identification number and registration identification information.

The smart card is a relatively new technology. AT&T recently introduced a smart card for use as a calling card. The costs will probably decrease as more applications are developed and in use. Currently, the applications of smart cards include:

- Electronic toll collection - Some toll authorities are now selling tolltags, a type of smart card, for use at toll plazas.
- Parking - Electronic payment of parking fees at airports, mass transit, and park-and-ride locations.
- Mass Transit - Service card for bus and rail transit fees.
- Concessions - Use of card to buy gas, food, etc.
- Fleet Management - Identification and taxation of interstate traffic.
- Ridesharing - Discounts for High Occupancy Vehicle (HOV) lanes.
- Congestion Pricing - Changing of road fees based on traffic volume.

RELATED APPLICATIONS OF IDENTIFICATION TECHNOLOGIES

Several States have implemented or are in the process of implementing identification technologies for driver's licensing and/or vehicle registrations. California has been issuing driver's licenses with magnetic stripes since 1991. Based on conversations with the Driver's License Section of the New York State Department of Motor Vehicles, New York has recently begun issuing driver's licenses with magnetic stripes and bar codes.

The statewide distribution will be phased in over a 4-year renewal cycle. Virginia will soon be issuing driver's licenses with magnetic stripes. Supposedly, requests for bids to produce driver's licenses with magnetic stripes have been released by New Hampshire and Quebec, Canada. Other States and Provinces that are examining the feasibility of adding magnetic stripes or bar codes include New Mexico, Illinois, Indiana, Maryland, and Ontario, Canada.

The new license issued by the California Department of Motor Vehicles (DMV) is a plastic, credit card-type driver's license that features a hologram, color photograph, and magnetic stripe. The new driver's license is the first of its kind in this country. The plastic license has a magnetic stripe on its back but does not have any raised letters as does a credit card. All alphanumeric information encoded on the magnetic stripe is the same as that printed on the front of the driver's license. The development of the license costs about $0.74/card over the 5-yr contract period. About 20 percent of California's 21 million registered drivers now have a license with a magnetic stripe. They are issuing about 600,000/month. The front and back sides of a sample driver's license are shown in figures 17 and 18.

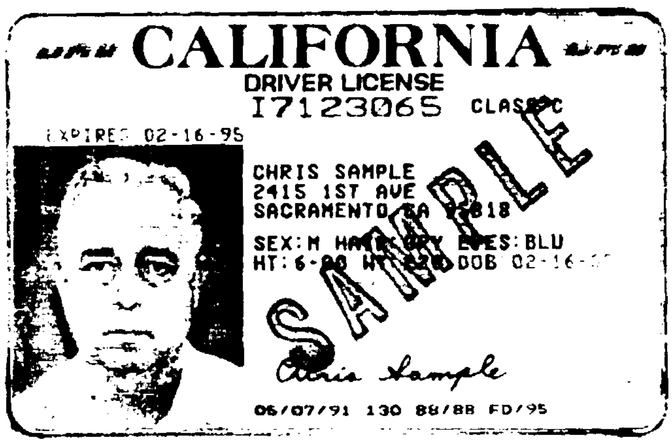


Figure 17. Front of a California driver's license.

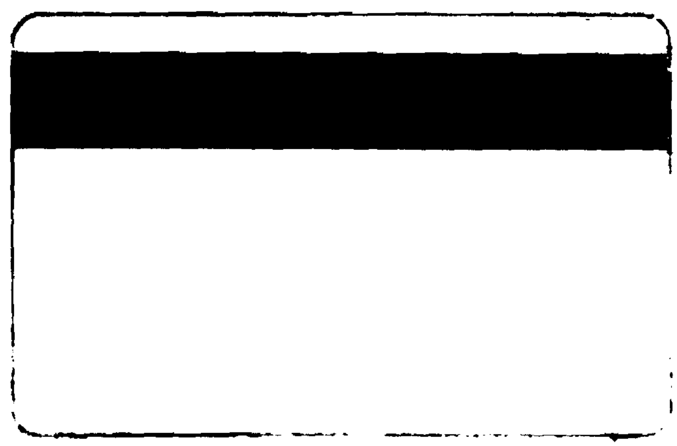


Figure 18. Back of a California driver's license.

The California Highway Patrol, Ventura Area, is conducting a pilot study of an Automated Citation Device (ACD). Selected CHP Ventura Area patrol officers are currently using the ACD, which is a palm-held computer that was developed by the Radix Corporation of Salt Lake City, Utah, for issuing citations. The Ventura County Court was experiencing problems with the legibility of citations issued by the officers of the California Highway Patrol, Ventura Area, which includes all of Ventura County. Under the sponsorship of the CHP, the Ventura Area of the CHP is participating in a small demonstration-type pilot project involving an Automatic Citation Device. Data from the driver's license can be entered into the device. Using a small thermal printer, the CHP officer can then issue a computer-generated citation to the driver. The ACD and the companion printer are shown in figure 19. A driver's license inserted in the magnetic stripe reader of the ACD is illustrated in figure 20. The current process showing how the citation device is used is illustrated in figure 21. A computer-generated citation is illustrated in figure 22.

Figure 19. Radix Corporation's Automatic Citation Device and printer.

Figure 20. Illustration of the magnetic stripe reader with a California driver's license.

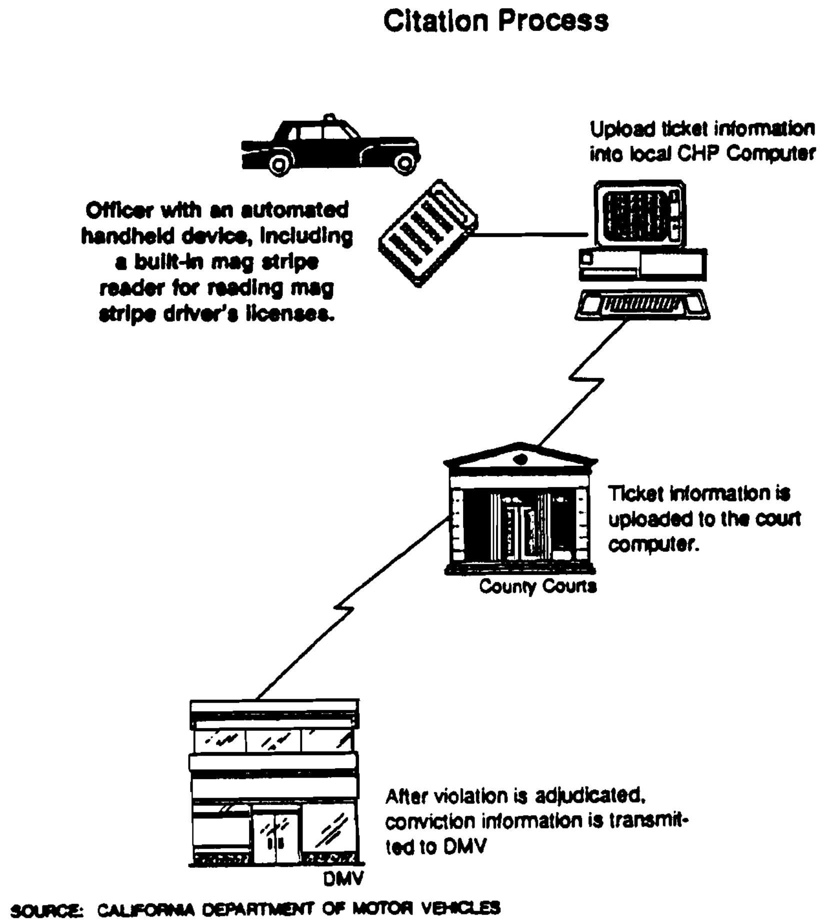


Figure 21. Process for using the Automated Citation Device to issue citations.

The palm-held computer has now been equipped with a magnetic stripe reader that allows the CHP officer to "swipe" the license of the driver who has been stopped for a violation. The CHP in Sacramento emphasized that this is an experimental project, there are no funds or plans for its expansion beyond the pilot, and research and development efforts have been curtailed by budget limitations. However, it is not beyond the realm of possibility to expect an expansion of this type of device and the possibility that a strategy will be implemented to make more effective use of the magnetic stripe on the driver's license, including its use for accident data collection. If funding becomes available, the DMV hopes that the demonstration project can be expanded. The proposed expansion would involve an evaluation of CHP officers accessing DMV driver records from the field. The process is illustrated in figure 23.

According to the California DMV and the American Association of Motor Vehicle Administrators (AAMVA), some automobile manufacturers are now placing bar codes on the plate with the VIN on the dashboard. Bar codes are currently being used for inventory management and other purposes. The draft master plan for the Registration, Title, Vehicle Dealers and Manufacturers (RTVDM) committee of AAMVA indicates that a project should be undertaken. Specific tasks would include the development of standards and specifications for bar-code software and hardware to assist jurisdictions in procurement and to facilitate uniformity.

CALIFORNIA HIGHWAY PATROL ☐ MISDEMEANOR
NOTICE TO APPEAR ☐ TRAFFIC ☐ NONTRAFFIC

DATE:	TIME	DAY OF THE WEEK	TICKET NO.
10/29/91	09:34 AM	TUESDAY	231246

NAME
JOHN N TEST

MAILING ADDRESS	CITY	ST	ZIP
123 N HERE ST	OJAI	CA	93023

DRIVERS LICENSE NO.	ST.	BIRTH DATE
NIP	CA	01/01/01

SEX	HAIR	EYES	HEIGHT	WEIGHT	RACE
M	BRN	BRN	5'10"	180	OTHER

VEH TYPE 0100 | VEH YEAR 91 |MAKE POR |CLR RD |BODY STYLE 2DR

VEH LIC TOO FAST |REG EXP 01/92|ST. CA |

REGISTERED OWNER OR LESSEE
SAME

MAILING ADDRESS OF OWNER OR LESSEE
SAME

FINAN RESPON: N | [ ]BOOKING REQ

(40610b VC) SEE REVERSE| VIOLATION(S) |CHP/DOT/PUC/ICC

| N | CVC 22349 EXCEEDING MAXIMUM SPEED LIMIT

| N | CVC 27315(D) FAILURE TO WEAR SEAT BELTS

| |

| |

SPEED APPROX	PF/MAX	VEH LIM	SAFE	AREA	BEAT	A.I.	SPECIAL
85	55			765	301		090

VIOLATION LOCATION: N/B SR-33 NYE

[ ] VIOLATION(S) NOT COMMITTED IN MY PRESENCE, DECLARED ON INFORMATION AND BELIEF.
I DECLARE UNDER PENALTY OF PERJURY UNDER THE LAWS OF THE STATE OF CALIFORNIA THAT THE FOREGOING IS TRUE AND CORRECT.
EXECUTED ON 10/29/91 AT (PLACE)
COUNTY CALIF

CHP OFFICER: J D DAVY ID:11995 VAC:00/00/00 - 00/00/OC

OTHER OFFICER: ID: AREA:

WITHOUT ADMITTING GUILT, I PROMISE TO APPEAR AT THE TIME AND PLACE DESIGNATED BELOW.

X SIGNATURE ______

TICKET NO. 231246

[X] MUNICIPAL COURT [ ] JUSTICE COURT [ ] JUVENILE [ ] TO BE NOTIFIED

ADDRESS
800 S VICTORIA AVE RM 118 VENTURA CA 93009

ON THE 12/09/91 APPEAR AT 12:30 PM

OR YOU MAY APPEAR AT ___ PM ON ______
TO ANSWER CHARGES OF VIOLATIONS DESCRIBED ABOVE

Form approved by the Judicial Council of California, Rev. 1-1-90 V.C. 40500, 40513(b), 40522 P.C. 853.9, 959.1
Form 215

Figure 22. A computer-generated citation.

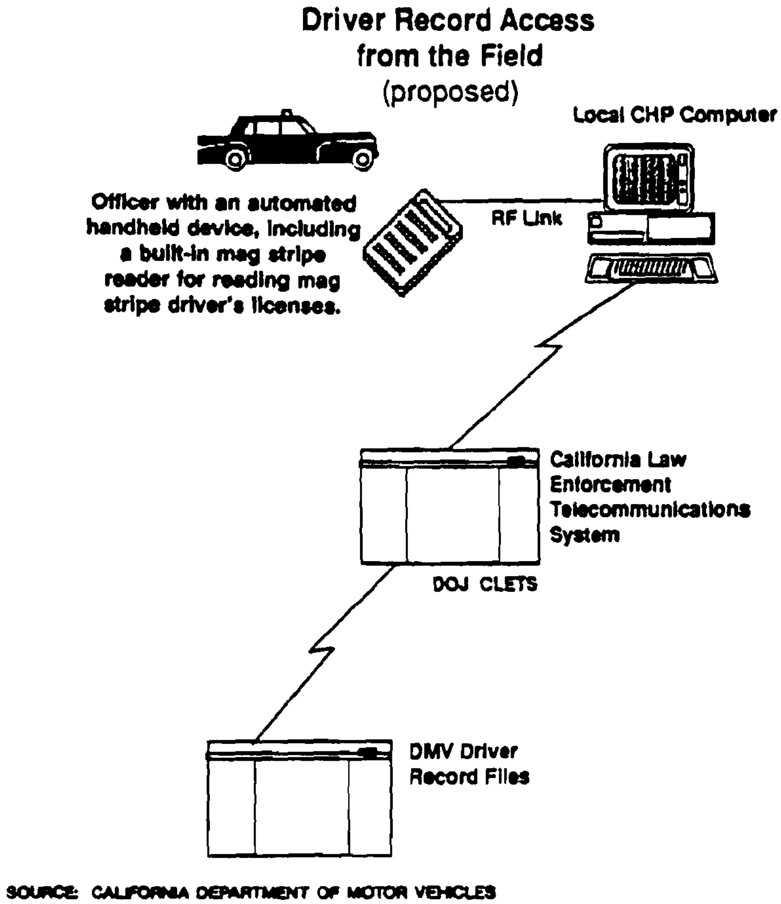


Figure 23. Process for remote access to California DMV's driver record files.

As indicated previously, the new driver's license for New York State has both a magnetic stripe and a bar code. The bar code contains a 9-digit driver identification number, which New York refers to as a client or customer number, the driver's date of birth and expiration date. The magnetic stripe contains information on the driver's name, address, city, class of license, restrictions, height, weight, eye color, and other information. The bar code is a single-density bar code written in US 128 code. They have reserved some space for a future security algorithm. In addition, New York has been issuing annual registration stickers with bar codes. This bar code, which is also written in Code 128, contains 22 characters of information, including the license plate number (up to 8 digits), the vehicle class (e.g., passenger car, rental car, etc.), the number of cylinders, and type of fuel. They use the bar code to calibrate emissions testing. The emissions monitoring equipment can be used to first read the bar code. This then creates a data record. Later, the data can be accessed by dialing in and then the data can be uploaded.

The California DMV indicated that their Bureau of Automotive Repair is interested in the use of bar coding so they can electronically transmit data related to smog checks. They are looking at single-density and double-density (e.g., one code on top of the other) bar codes. They hastened to point out that double density bar codes will require special reader equipment. Most bar-code readers can read up to 20 characters. They are considering bar coding the VIN, year, make, and model of the automobile on the DMV record for microfilm indexing and on the customer smog check record.

RELATIVE COMPARISON OF IDENTIFICATION TECHNOLOGIES

At this point in time, magnetic stripe as an identification technology to store driver or vehicle information offers benefits compared to the conventional bar codes. Currently, most bar-code readers that are commercially available can read up to 20 characters. While this may be adequate for a driver's license number, it is not adequate for additional information on the driver (e.g., driver's name, address, date of birth, etc.). Similarly, single density bar codes could be used for the unique, 17-digit Vehicle Identification Number. Yet, there would not be sufficient space to also encode vehicle owner's name, address, vehicle make, vehicle model, and vehicle year. To rely solely on single-density bar-coded information would require a subsequent query of a driver's license data base or a vehicle records data base.

Smart cards can store much more information than a magnetic stripe. Unlike a magnetic stripe, physical contact with the smart card is not required because of their radio frequency capabilities. One of the major drawbacks to the use of smart driver's licenses is, however, that police will need portable smart card readers at the accident scene. There are obvious benefits to allowing the police officer to capture the identification information while standing outside the police vehicle. Moreover, the current state of the art in smart card production technology does not lend itself to low cost. Whereas the unit cost per driver's license with magnetic stripe is on the order of $0.74 to the California DMV, the unit cost for a smart card is on the order of $20.

APPLICATION OF PERIPHERAL EQUIPMENT FOR IDENTIFICATION TECHNOLOGIES

Identification technologies can be implemented for driver's licenses, vehicle registration cards, or vehicle title cards. In addition, identification technologies can be attached to or mounted in the vehicle itself. Detailed study of the development and implementation of these identification technologies by State motor vehicle departments was beyond the scope of this project. Rather, this investigation of identification technologies focused on the peripheral equipment that would be required to capture data from a magnetic stripe, bar code, or smart card. The key question was if the State implements an identification technology, then what does the police officer need to make maximum use of the magnetic stripe, bar code, or smart card?

It is important to clarify that from the perspective of accident data collection, magnetic stripes, bar codes, "smart" cards, and other identification technologies are not very useful in a stand-alone format. They are only useful when used in conjunction with a laptop, notebook, pen-based, portable, or some other computer or recording device. Consider the situation of a local police officer in California investigating a traffic accident. Without a magnetic stripe reader, the information on the magnetic stripe on the back of the California driver's license has no value. Moreover, even with a magnetic stripe reader, the officer still must collect the other information on date, time, location, environmental and weather conditions, vehicle characteristics, and other parameters. It would be counterproductive to have the officer only enter driver and/or vehicle information at the scene without entering all the required data to create a complete traffic accident record. The officer needs a portable computer with accident report data entry software in addition to the identification technology reader device. For this reason, providing driver and/or vehicle identification technology without the use of computers by police officers was not considered a viable alternative.

Implementation Schemes

There are two basic scenarios to consider in implementing the peripheral equipment. The first assumes that the police officers already have laptop or notebook or pen-based portable computers. To implement the peripheral equipment, the computer would have to be retro-fitted or the RS-232 serial port would have to be utilized. The second scheme assumes that the police officers do not have any computers. For this scheme, the computer could be manufactured or equipped with an integrated reader. With either scheme, greater benefits can be achieved if there is data communications to transmit and receive information. Consider, for example, that a radio frequency data link allows the officer to "swipe" the driver's license and then transmit the data to the local dispatcher. The local dispatcher could then access, via dedicated phone lines, the central motor vehicles department's computer and check that driver's profile (e.g., outstanding warrants, revoked licenses, etc.). This information could then be transmitted back to the officer at the scene who could take the immediate and appropriate response. In other words, the officer could use the data link to run an automated driver's license check. Similarly, an automated check of vehicle information could be made if there is a digital communication link between the filed computer and vehicle registration files.

Equipment

Peripheral equipment can be added to or integrated with laptop, notebook, and pen-based computers to automate the collection of driver and vehicle identification data. The types of peripheral equipment, which are specific to the identification technology, include magnetic stripe readers, bar-code readers, and smart card readers. These are discussed separately in the following sections.

Magnetic Stripe Reader

A keyboard interconnect cable is used to interface the magnetic stripe decoding unit between the computer keyboard and the computer. This allows the decoding unit to act as a keyboard emulator. Some manufacturers provide the magnetic stripe reader as a separate unit connected to the decoder via a cable, whereas other manufacturers have developed the decoder and magnetic stripe reader as one integrated unit. The decoder unit can also be attached to a computer's serial port via an RS-232 cable, instead of being used as a keyboard wedge. The configurations are discussed below:

(1) Separate Reader and Decoder Unit - In this configuration, the reader and the keyboard are connected to the decoder unit. The decoder unit is then connected to the keyboard

port in the back of the computer. This configuration operates as if the data were entered directly from the keyboard. No additional software is required.

(2) Integrated Reader and Decoder Unit (Keyboard Wedge) - This configuration reburies a Y-connector that allows both the reader device and the keyboard to be connected to the keyboard port in the back of the computer. Under this configuration, the magnetic stripe is scanned as if the data were typed directly from the keyboard. No additional software is required in this case.

(3) Integrated Reader and Decoder Unit (RS-232 Serial Port) - In this configuration, the reader device is connected to the RS-232 serial port in the back of the computer. The scanned data is sent directly to the RS-232 port. Memory resident software is required to route the data from the serial port into the keyboard buffer. This will allow the data to be accepted as if it was entered directly from the keyboard. This software is available from some bar-code and magnetic stripe reader manufacturers. Software can also be purchased off-the-shelf to perform this function. This configuration is useful if the computer contains an integrated keyboard. (Laptops and notebook computers have integrated keyboards.) Note that some "dummy" terminals do not contain a serial port, and therefore, one of the other configurations must be selected.

With some integrated reader and decoder units, only limited functions may be available. In these cases, the data are scanned and then sent to the computer without any additional capabilities. Decoders can perform several functions that may not be available with an integrated reader and decoder unit:

- Several bar-code and magnetic stripe readers can be connected to the decoder unit. This is useful if the application utilizes both bar-code and magnetic stripe technology.
- Additional bar-code symbologies may be supported.
- The scanned data can be manipulated before it is passed into the accident form. For example, the data can be stripped, paused, converted to uppercase, etc.
- User-defined editing functions can be applied to the scanned data.
- A preamble and/or postscript can be applied to the scanned data.
- Some decoders contain an RS-232 serial port that can accept data from a serial input device. The other features of the decoder unit can then be utilized with this data (e.g., keyboard emulation, data manipulation, editing, etc.).
- The decoder unit can be configured to operate with other types of keyboards. Integrated reader and decoder units do not necessarily support all types of keyboards.

The average price for a complete magnetic stripe reader system is approximately $300 to $450. The addition of a decoder unit would increase the price by approximately $100 to $400. Quantity discounts are also available, depending on the vendor. Accessories such as extension cables and a power supply are available. Note that the battery in the enforcement vehicle may be used as a power supply for the magnetic stripe system.

Bar-Code Reader

For the collection of accident data, a portable handheld scanner is required. Portable bar-code scanners include wands, charged coupled device (CCD) scanners, laser beam readers, and slot readers. It is important to recognize that some bar-code readers are not compatible with all bar-code symbologies. Accessories such as an input device holder, extension cables for the input device, and a power supply are available. For all the input devices, unit prices are affected by the different symbologies supported and the level of programmability for a particular application. Quantity discounts are also available, depending on the vendor.

Wands typically look like fat marking pencils. Wands must touch the coded surface and are useful when scanning identification cards. Wands can be connected directly to a computer through an RS-232 serial port. This type of connection would not require any modification to the existing computer hardware. Wands are the least expensive of the three input devices. Bar-code wands, which can be made to be integrated with the pen instrument for pen-based computers, cost approximately $400.

Charged coupled device (CCD) scanners actually photograph the bar code, converting the optical image into an electrical image. As a result, CCD scanners provide an extremely fast scan rate. CCD scanners are usually in the shape of a gun. CCD scanners do not require contact with the bar-code label. The maximum scanning distance is approximately 1 in (25 mm) from the label with a maximum label width of approximately 2.5 in (64 mm). CCD scanners can also be connected directly to a portable computer through an RS-232 serial port. CCD scanners, which are more expensive than slot readers and wands, cost approximately $700 per unit.

Laser scanners are usually in the shape of a gun and are generally the most expensive type of input device. The unit price is currently on the order of $1,250. Laser scanners do not require contact with the bar-code label and are useful when the coded surface to be read is at a short distance from the scanner, such as reading the VIN through the windshield. Typical scanning distances are from 2 to 18 in (51 to 457 mm). Laser scanners can also be connected directly to the computer through an RS-232 serial port. The laser scanner is also the least durable of the four types of portable bar-code readers since it is an electro-mechanical device with moving parts.

Slot readers are designed for reading identification cards, such as a driver's license. The bar code is scanned as the card is run through the slot. With a slot reader, the bar codes must be positioned accurately on the identification card. The use of a slot reader would therefore require identification cards to be standardized in terms of the position of the bar codes. Currently, slot readers that connect directly to the computer are not available. If a slot reader is being used, a separate decoder unit is required. The slot reader is connected to the decoder, and the decoder is connected to the computer through an RS-232 serial port. Slot readers tend to be slightly more expensive than a standard wand device. The cost of a bar-code slot reader with the decoder unit is on the order of $600.

Wands, charged couple devices, and laser scanners can also be configured with decoder units. A decoder unit for these input devices would only be advantageous if another scanning system, such as a magnetic stripe system, is being used in addition to the bar-code system in the enforcement vehicle. The decoder unit would require additional space in the enforcement vehicle. The dimensions of decoder units are approximately 5 in by 5 in by 1.5 in (127 mm by 127 mm by 38 mm). The addition of a decoder unit for a bar-code wand, CCD, or laser scanner would increase the unit price by approximately $100 to $400.

For all of the configurations discussed above, the bar-code reader sends data to the computer system through a keyboard interface. Data appears as though it was typed in from the keyboard, thus adding bar coding capabilities to applications (e.g., automated accident forms) without software modifications.

Smart Card Reader

Smart card readers can also be used as peripheral equipment for laptop, notebook, and pen-based clipboard computers. In the simplest and least expensive configuration, a smart card reader is installed in the enforcement vehicle. The smart card reader is designed to house a smart card and is about the size of a calculator. The smart card reader is powered by an internal 9V battery. The smart card reader is connected to the computer system in the enforcement vehicle through an RS-232 serial port. To obtain the driver and vehicle information from the smart card of the driver of the accident vehicle, the smart card is inserted into the smart card reader in the enforcement vehicle. The data from the smart card reader is then transmitted in ASCII format to the computer system. To integrate this ASCII driver and vehicle information into a computerized accident form would require the development of customized software. This differs from bar-code and magnetic stripe readers, which act as a keyboard interface and do not require any software modifications to the computerized accident form. To allow this data to be entered automatically into a computerized accident form as if it was typed directly from the keyboard would require memory resident software to route the data from the serial port into the keyboard buffer. Alternatively, other types of configurations can be developed that would allow the data to be sent directly to the keyboard buffer or elsewhere into the computer for further manipulation. A complete portable automatic vehicle identification (AVI) reader system currently costs approximately $5,000; however, some manufacturers offer quantity discounts.

Anticipated Benefits

Benefits derived from these technologies were described at the beginning of this chapter. They include the following:

- Reduction in errors in the accident records data base related to driver's license number, driver's name, driver's address, driver's age and/or date of birth, license plate number, vehicle identification number, vehicle owner's name, vehicle owner's address, and vehicle make, model, and year. If drivers had these identification technologies and the police had readers to capture the data, then errors associated with illegible handwriting and transpositions would be substantially reduced.

- A time savings to the police officer who is completing the accident report form.

- Reduction in work load to the data processing personnel at the State data center and/or a corresponding reduction in labor costs.

In addition, the use of identification technologies are advantageous in that they may reduce or eliminate counterfeit or forged driver's licenses and vehicle registration cards.

Limitations/Disadvantages

Durability is always a key concern with respect to encoded data on bar codes and magnetic stripes. Data on a magnetic stripe card can be corrupted, scrambled, or erased if the card comes in contact or in close proximity to a magnetic field. The strength of the magnetic field will determine how close the card must be to the magnetic source before data is corrupted or lost. No protection is available if the card comes within a magnetic field. Credit cards, transit cards, etc. currently use magnetic stripe technology, and data corruption and erasure problems are minimal. If the critical driver or vehicle data is also shown on the front of the card, then this would allow a police officer to manually enter the data if the magnetic stripe cannot be read.

Utilization is another issue. A police officer will not be able to use the reader equipment if the driver has a license issued by another State unless that issuing State uses the same standardized identification technology. It is highly unlikely that all States will adopt the same identification technology, let alone abide by the same standards with respect to driver licenses or vehicle registrations.

Each reader device also has its own limitations and disadvantages. These include the following:

- Magnetic Stripe Readers - The potential exists for data corruption and data loss due to misuse/neglect or if the magnetic stripe comes in contact or close to a magnetic field. Only approximately a total of 120 characters of information can be stored on all three tracks of a magnetic stripe. If a decoder unit is required, additional space in the enforcement vehicle may be required. The dimensions of a decoder unit are typically 5 in x 5 in x 2 in (127 mm x 127 mm x 51 mm).

- Bar-Code Readers - If bar coding is used for vehicle registration purposes and the bar code is placed on the vehicle itself (e.g., on a sticker on the windshield or on top of the dashboard under the windshield), a laser scanner would most likely be required since it is the only bar-code reading device that can read bar codes from several inches away. This is the bulkiest and least durable of all bar-code reading devices. In addition, visibility problems in scanning the bar code may develop under adverse weather conditions. Compared with magnetic stripe and smart card technologies, bar codes store the least amount of information in the space available on an identification card. Only approximately 20 alphanumeric characters can be stored on a typical identification card, depending on the bar-code symbology used. Bar codes can be illegally duplicated or changed. Similar to the magnetic stripe reader, additional space in the enforcement vehicle may be required if a decoder unit is required.

- Smart Card Readers - Since smart cards and smart card readers are a relatively new technology, there are very few manufacturers. If the radio frequency capabilities of the smart card are utilized for accident data collection, an AVI reader device would be required in the enforcement vehicle. The disadvantages of this configuration include:

    - High cost, currently approximately $5,000 for a portable AVI reader.

    - Additional space would be required in the police vehicle. The current dimensions of a portable AVI reader are approximately 5 in x 4 in x 9 in (127 mm x 102 mm x 229 mm).

    - The consumer may object to the use of smart cards because of privacy issues since the data on a smart card can be retrieved using radio frequency devices without the driver's consent.

CHAPTER 6. TECHNOLOGIES FOR AUTOMATING THE COLLECTION OF LOCATION DATA

Although it is a critical piece of information necessary for the identification of locations with high accident rates or frequencies in accordance with the Federal Highway Safety Program Standards, location data are particularly deficient in terms of quality and are costly to obtain. The need for reliable and accurate accident location information is paramount for a successful safety management program. A location technology could be used by police officers to record additional information (e.g., latitude and longitude) about the accident location on the report form. For many States, the improvements in the quality of location data to be gained from the application of location technologies can be quite significant.

LOCATION TECHNOLOGIES

For this project, location technologies that were investigated include the Loran-C, map matching and dead reckoning systems, cellular phones, and Global Positioning System (GPS). These technologies have the potential to improve the quality of accident location data and reduce the demands and costs associated with coding, keypunching, and processing accident location information for police accident reports. These locational technologies can be installed in police vehicles to display locational information (e.g., a GPS receiver can display a latitude and a longitude). A police officer could write down this information on the accident report form in addition to information that is currently recorded (e.g., road name, route number, intersecting street, etc.). Alternatively, the police officer could also be equipped with a computer. With the proper linkage between a stand-alone location device (e.g., a GPS receiver) and a computer, or with the locating capability built into a computer, the location information could be captured and electronically pulled into a computer-based record for the accident. The computer linkage obviates the need to write down the information. Furthermore, it reduces a myriad of errors associated with the following:

- The officer incorrectly recording the location information on the form.
- The officer leaving the field blank on the form.
- Keypunching errors.

For these reasons, there are significant benefits to using computers equipped with the location technologies.

It should also be noted that depending on how they are designed and used, these location technologies also can be applied to improve the accident notification and response process. For example, the technology could provide positional information on the location of police vehicles to the local police dispatcher. This could result in a reduction in police response time. In addition, invehicle navigation systems that utilize the location technologies and a Geographic Information System (GIS) could allow police to find optimum routes.

Loran-C

Loran-C is a well established, long range navigational system that has been installed throughout the world to guide ships within radio range of the shore. The U.S. Coast Guard and their equivalents in other countries maintain a series of radio transmitters at fixed locations around their countries. Each of these transmitters broadcasts a unique identity code on a low radio frequency. A Loran-C receiver detects the radio frequency transmissions received from a master transmitting station and two or more secondary stations. By calculating the distances to those fixed stations, the current location of the Loran-C receiver can be calculated using triangulation pattern techniques. This system is used by all major shipping companies for locating vessels. There has been some research of potential automatic vehicle monitoring and location systems based on this technology.

Although this system has been designed primarily for shipping, the U.S. Coast Guard has also installed inland transmitters. Consequently, for some areas, it is possible for the system to be used for vehicle location. The application of Loran-C is likely to be limited to roads where the positioning accuracy is not so critical. The accuracy of Loran-C is generally less than 650 ft (200 m). A study conducted in Los Angeles found that mean and 95th percentile errors over a 30-mi^2 (80-km^2) central area were approximately 650 ft (200 m) and 1,700 ft (500 m). That same study found that the mean and 95th percentile errors over a 400-mi^2 (1,000-km^2) area were approximately 1,500 ft (450 m) and 2,800 ft (850 m), respectively.[(4)] The inland stations are typically near navigable bodies of water. Accuracy decreases for location measurements on land as the distance increases from the inland stations. Loran-C receivers cost less than $500. As with other locating systems, the availability of a map base that allows the analysis to take the latitude and longitude readings and turn them into a readily understandable location would be required. Motorola, Inc. currently markets a LORAN-C system known as Tracknet AVL-200 and II Morrow, Inc. produces a LORAN-C based, automatic vehicle location (AVL) system called the Vehicle Tracking System (VTS).[(5)]

Map Matching/Dead Reckoning Systems

While systems that utilize external input for position data rely on communications signals that might be blocked or disrupted by natural or manmade structures and electromagnetic interference, self-contained vehicle navigation systems do not necessarily depend on satellites, transmitters, or any other devices external to the vehicle. Self-contained navigation systems may utilize dead reckoning alone or combine with map matching to determine vehicle position.

Dead reckoning is a process of navigation based on the fact that when starting from a known position, if the heading and distance traveled are accurately monitored, the current position can always be calculated. In vehicle systems, the input for heading is supplied by a compass and/or a gyroscope. The input for distance traveled is supplied by wheel sensors. All dead reckoning systems are dependent upon motion data for accuracy. In vehicle systems, compass readings may be inaccurate due to electromagnetic interference or natural variations in the earth's magnetic field. Distance data will be inaccurate due to road surface variance, mechanical maladjustments, and other anomalies. Errors may be reduced to some extent by using estimates of sensor error in the position calculations. However, for more accurate positioning, another source for position data is required periodically to update the dead reckoning position and offset accumulated errors.

One source for ascertaining current position is map matching. With map matching, computer algorithms are used to match the current position as estimated by dead reckoning against a digital map. For example, the map matching algorithm used in the Travelpilot IDS developed by Etak, Inc. and Bosch uses five major tests against a probability distribution function of the most likely position known as the contour of equal probability. If the match is successful, the current position is updated. The Travelpilot also notes systemic errors and applies them to the systems calibration constants. The Sumitomo map matching algorithm operates similarly, although the Sumitomo system uses beacon input as part of its position data. The Travelpilot user interface includes functions for manually correcting vehicle position on the map display.

The accuracy of a system that relies on both dead reckoning and map matching is dependent on the hardware components, the accuracy of the software algorithms, and the digital maps. To some extent, map accuracy is a function of the map producers success in the marketplace. If there is a greater market demand for digital maps, then the maps are likely to be of a higher quality. Other factors that influence map accuracy include the frequency of road construction in the area and the accuracy of source base maps that are used as the basis for many commercially produced digital maps.

One approach for improving the accuracy of autonomous navigation systems is to supplement position data with input from external systems. For example, the autonomous system would periodically poll for position data from a GPS system and correlate that information with its dead reckoned position. This approach is being used in the TravTek IVHS project in Orlando, Florida. The primary disadvantages are cost and added complexity of the systems.

Vehicle navigation systems typically include or can be easily adapted to include a serial communication port that can be used for automatically reporting the current position to another computer system. For accident data collection, this port may be connected to a portable computer that is being used for recording other accident data. This would eliminate errors in transcribing location data from a navigation system screen.

The hardware components of autonomous navigation systems that use dead reckoning and map matching typically include the following:

- A main processing unit - this includes processor, memory, power supplies, a compass and/or gyroscope, and interfaces to other devices; for automobiles, the main unit is often placed in the trunk.

- A display unit - this is a high resolution computer display screen sized to fit within a vehicle environment; smaller screens are used for automobiles and larger screens are used for vans and trucks. The screen display may be monochrome or color; current technology is Cathode Ray Tube (CRT), future technology may incorporate Liquid Crystal Display (LCD). The unit is typically positioned so that the screen can be read with a quick glance.

- A map storage device - this may be magnetic tape cassette (slow, small capacity) or compact disk (faster, large capacity), usually integrated into the main processing unit.

- Wheel sensors - a magnetic or optical sensing device that measures speed by sensing wheel rotation; turning movements are sensed by comparing speed of wheels on opposite sides.

Installation of these devices requires considerable space in the trunk and in the dashboard area. As an example, the Travelpilot processor cabinet requires a space approximately 13 in (330 mm) wide by 10 in (254 mm) deep by 4 in (102 mm) high and the smaller monochrome monitor is 5 in (127 mm) wide by 6 in (152 mm) deep by 4 in (102 mm) high. For police vehicles that may already be outfitted with radios, computers, radar, and the like, space requirements present a problem. As with most computer-related devices, the trend is towards smaller, less expensive, and more powerful systems.

The cost for autonomous navigation devices is considerable. The first generation Etak Navigator, which used cassette tape for maps, cost approximately $2,500 plus the cost of maps, which may be $500 for a large metropolitan area. The Bosch Travelpilot cost $3,400 plus $500 for a map. The cost for navigation devices in emergency vehicles may be leveraged over multiple applications. For example, the system can serve as part of an automated dispatch system wherein the incident location is displayed on the map along with a description of the incident type in order to improve incident response times. Such a system must have the ability to track the current location of all vehicles and base the dispatch decision on need and availability.

Cellular Phones

Cellular telephones are another technology that potentially can be used for automating vehicle location. Cellular phone networks are formed by stratifying an area into multiple cells and installing land stations with antennas in the center of each cell. These station antennas receive the radio frequency signal transmitted by cellular phones. It is possible, with the available technology, to utilize the radio frequency signals generated by cellular phones to determine in which cell the vehicle is based on the strength of the signal received at three or more land stations. Currently, private service companies are using cellular phones as a means of locating stolen vehicles by associating the cellular phone number with cell site areas.

In order to pinpoint a vehicle's location to meet the needs for accident reporting, additional infrastructure is needed. As of June 1992, the only vendor offering technology that utilizes cellular phones to obtain accurate vehicle location information is KSI, Inc. KSI's system is called the Direction Finding Localization System (DFLS). KSI currently has an operational prototype in Annandale, Virginia and is planning a test site to be developed in the Detroit or Houston area in 1992.

To utilize cellular phone technology to obtain location information, an infrastructure of receiving antennas must be established. If a cellular network already exists in the desired area, additional equipment would be required for each of the cell sites. Each cell site would require another antenna connected to a computer at the base system via cables. Specially designed receivers, analog/digital converters, filters, amplifiers, and digital signal processors must also be included with the computer system. It is estimated that this additional equipment would cost approximately $150,000 to $200,000 for each cell. For example, the Baltimore-Washington area currently has approximately 100 cells. To equip all of these cells would require approximately between $15 million and $20 million. These costs will be higher if a cellular phone network does not exist. Also, further research and development is needed to determine if additional sites would be needed to support the use of cellular phone technology to obtain location information. For example, optimal spacing of the cell site antennas is approximately 3 mi (4.8 km) apart for calculating location information, but existing cell sites may be spaced only 5 mi (8.0 km) apart. Conversely, current cell site separation distances may be more than adequate for the needs of obtaining location information.

This type of system is based on topography and line of sight. In certain areas, such as urban areas with tall buildings, the radio signal of the cellular phone may bounce off buildings and other tall obstacles. This could potentially distort the accuracy of the calculated location information. This could be improved, however, by increasing the density of the cell sites, i.e., by placing the cell sites closer to each other. This may require the construction of additional cells. Although this system could potentially increase the load on the cellular network, the system would not reduce the number of calls a cellular network could handle or increase static interference.

This type of system would probably be offered through a "subscription service" (when available). Agencies (e.g., a motor vehicle agency) using this system would pay a fee to a service that maintains location information on a real-time basis for all cellular phones that are turned on in the area. Note that this does not require a conversation to be occurring over the cellular phone. Associated with each cellular telephone is a telephone number on an electronic serial number that is transmitted automatically to the cell's receiving antenna. The company offering the subscription service would maintain a data base that can be queried based on the telephone number or electronic serial number (or other information). This system could output the location of the cellular phone based on the last transmission, or if more up-to-date location data is required, initiate a transmission to the cellular phone in question to obtain the current location of the vehicle.

In the enforcement vehicle, a communications device could be incorporated into a portable computer or mobile data terminal (MDT) and dial into the service when desired. This system would then extract the location information and display it on the CRT and/or integrate the data automatically into a computerized accident form. Alternatively, a dispatcher could dial into the location data base computer to obtain the required location data for a particular cellular phone and transmit this information verbally to the officer in the enforcement vehicle. Note that the location can be output in various types of units, such as latitude/longitude, State/plane coordinates (measured feet), or the nearest street address. The accuracy of accident location information obtained using this technology is based on the distance between the cellular phone and the cell site receiving the signal of the cellular phone. Generally, the location coordinates are accurate to within approximately 25 ft (8 m) for each mile between the cellular phone and the associated cell site.

Global Positioning System (GPS)

The Global Positioning System (GPS) was developed and is operated by the U.S. Department of Defense. GPS is based on a constellation of NAVSTAR (Navigation Satellite for Timing and Ranging) satellites orbiting the Earth in 12-hour orbits. The complete GPS constellation will consist of 24 satellites: 21 for full coverage and 3 spares. In January 1991, worldwide 24-hour coverage for two-dimensional positioning and 16 hours of three-dimensional positioning was achieved with 16 satellites. With the successful launch of a satellite from Cape Canaveral on July 7, 1992, the number of active satellites reached 19. Full deployment is expected by early 1993. Each satellite is under the command of a ground control station that keeps track of the satellite's condition and position. Each GPS satellite continuously broadcasts two signals: a C/A-code signal for worldwide civilian use and a P-code signal for U.S. military use only. The C/A-code is a spread spectrum signal broadcast at 1575.42 MHz that is resistant to multipath and nighttime interference and is unaffected by weather.

GPS receivers collect the radio signals and internally calculate the user's location based on a set of simultaneous measurements of distance to three or more satellites and the associated time delay. Three satellites are required for two-dimensional positioning (latitude and longitude), and four satellites are required for three-dimensional positioning (latitude, longitude, and altitude). Receivers use the interval between the transmission and the reception of the GPS signal to calculate distances from each satellite and then use these distances in algorithms to compute position. Since GPS receivers passively acquire the satellite signals, the number of GPS users is unlimited.

Currently, a C/A-code GPS receiver can provide position information with an error of less than 82 ft (25 m) and velocity information with an error of less than 1.6 ft/s (0.5 m/s). GPS is more accurate than other positioning technologies such as Loran and Omega. It is not affected by factors such as weather, geographic location, or electrical interference. It is, however, affected by obstructions, such as tall buildings and tunnels, that interfere with the radio signals received from the orbiting satellites. In canyons of tall buildings, for example, the satellites are out of view, and the positional fix is lost. There are new GPS devices about to come on the market that utilize solid state gyroscopes.

Because GPS was developed by the U.S. Department of Defense for military applications, the U.S. Department of Defense implemented a policy known as Selective Availability (SA) in the fall of 1991. Random errors are inserted into the system to reduce the GPS C/A-code position accuracy to 328 ft (100 m) horizontally and 512 ft (156 m) vertically. A technique called differential GPS (DGPS) overcomes the effects of Selective Availability and also provides increased overall accuracy. Under differential GPS, one or more GPS receivers are placed at precisely known locations. The known position information is compared with the reading obtained from the GPS receiver at that location. The difference is then used to calculate corrections for the GPS signal. The error corrections can then be communicated via radio frequency or data link to other specially equipped receivers in the area. The resulting accuracy is 7 ft (2 m) horizontally and 16 ft (5 m) vertically. There are some receivers that have been designed for surveying and other purposes that can improve the accuracy with differential processing to within inches, but these receivers are very expensive.

It should be noted that differential processing is usually done in real-time. The correction can be transmitted over a radio frequency and received by a differential GPS receiver. The Coast Guard and the International Association of Lighthouse Authorities are experimenting with the feasibility of using radio beacons to transmit GPS corrections. Swedish and Finnish authorities are currently testing a differential GPS system which is helping cruise ferries navigate the passage between Stockholm and Helsinki. Alternatively, the correction can be continuously transmitted over a dedicated data line. Although it is not generally done, it may be possible to record readings at the control GPS receiver stations continuously, store the readings, and use them later as a look-up data file. Software could be developed to compare a reading recorded at a specific time at an accident scene with this data file and *de post facto* perform differential processing to correct for the distorted signal.

A sample of other existing GPS applications includes:

- Monitoring the location of vehicles for the TravTek project. Sponsored by General Motors, Federal Highway Administration, American Automobile Association, Florida Department of Transportation, and the City of Orlando, the TravTek project is an innovative project where 100 General Motors cars have been instrumented with invehicle navigation systems that receive and process traffic condition information in real-time. The vehicles also act as probes, sending location and speed information to the traffic management center. For the TravTek project, GPS is used for vehicle navigation and routing, as well as assisting in the identification of nearby attractions, accommodations, and services that are in close proximity to the vehicle.

- The Dallas Area Rapid Transit (DART) is planning to install a vehicle tracking system for its buses that will make use of a GPS. Tests have shown that the system can track vehicles to within 20 ft (6 m) of their actual position.[(6)]

- Monitoring the progress of freight trucks in the field by dispatchers to trace cargo movement and advise customers of projected delivery times.

Optional peripherals for GPS receivers include the following:

- Cables for transferring location data to a computer.

- An antenna for improving the ability to receive satellite signals in marginal conditions.

- Reference station and/or data transfer equipment.

- GIS software for mapping and vehicle location monitoring.

- Radio communications hardware that relays the position of a vehicle equipped with a GPS receiver to a central dispatcher.

A growing number of companies are building and selling GPS receivers. These include major diversified electronics companies such as Magnavox, Motorola, Honeywell, and Raytheon, and new GPS-oriented enterprises such as Trimble Navigation, Ashtech, and Magellan. Foreign companies such as Japan Radio Company, Global Wulfsberg, Standard Elektrik Lorenz, Sercel, and Shipmate have GPS products on the market, and more competitors are entering the marketplace every day. Systems integrators are designing inter-operable GPS units that work with other navigation systems, such as Loran-C, Omega, and Decca, and with other technologies such as GIS, sonar and other acoustic systems, and terrestrial or satellite communications systems.

RELATIVE COMPARISON OF LOCATION TECHNOLOGIES

Of the four location technologies evaluated, it appears that cellular phone technology, as it exists today, may have the least potential due to the high infrastructure costs. Even though the unit cost of a cellular telephone is as low as $50 and the cellular coverage in major urban areas is growing, the costs appear to be too prohibitive to install a sufficient number of additional towers so that police officers can identify their positions with a relative and absolute degree of accuracy. In the future, as the technology of using cellular phones for automatic vehicle location improves and the market to provide such a service extends to allow sharing the costs of the infrastructure, then cellular phone technology may become a cost-competitive solution.

One of the major relative advantages of the self-contained navigational systems is that they do not rely solely on external satellite signals, radio signals, or other equipment outside the vehicle. Consequently, they can operate effectively in areas with tall buildings, in canyons, and in tunnels. Moreover, these systems are not affected by adverse weather and other factors that influence the reception of radio waves and external signals. For the intended purpose of providing improved accident location data, a dead reckoning/map matching navigation system is sufficiently accurate. This is especially true for systems that allow the user to manually adjust the vehicle location on the map display screen. However, the costs to install map-matching systems in all police vehicles and the space requirements within the police vehicle are significant impediments to the implementation of self-contained navigational systems. The costs can be even higher if accurate and reliable digital map data bases need to be created for the applicable area or State.

With respect to Loran-C technology, one of the major drawbacks is that there is a lack of coverage for the central United States. Problems have also been encountered in receiving Loran-C transmissions in urban areas because of multipath reflections and the deflection of the signals.[4] The University of Calgary in Canada recently conducted a comparative analysis of Loran-C and GPS for land vehicle navigation. It was found that the accuracy of Loran-C is equivalent to that of GPS while Selective Availability is enabled. Thus, without Selective Availability, Loran-C is much less accurate than GPS.

At its current state of development, it appears that GPS offers relative advantages over the location technologies. The advantages include the following:

- GPS technology provides increased accuracy.
- GPS is an emerging technology. While there are currently only a limited number of manufacturers and distributors of GPS receiver technology, more are entering the market. GPS receiver prices have already decreased significantly from several thousand dollars per unit. It is anticipated that the unit cost will continue to decrease.
- Worldwide coverage is available with GPS receivers. Loran-C is not available in all areas.
- Compared to the other location technologies as they exist today, GPS is relatively inexpensive to implement. Cellular phone technology requires additional expensive infrastructure. Map-matching/dead reckoning systems require extensive equipment to be installed in each police vehicle. The unit cost of installing a GPS receiver in a police vehicle is substantially lower compared to the per-vehicle cost for a self-contained navigational system.
- GPS is not affected by weather, geographic location, or electrical interference, although there are potential black holes in terms of reception.

SAFETY-RELATED GPS APPLICATIONS

As part of an Alaska Department of Transportation study, four Alaska State troopers have been using GPS receivers for recording accident location on accident reports. Although the study is still in the evaluation stages, a grant from the Department of Public Safety allowed the purchase of two Trimble Transpack and two Magellan 1000 handheld GPS receivers. They paid approximately $2,300 for the Trimble receivers and $1,650 for the Magellan receivers. The receivers were given to four State troopers who cover large, very rural areas. The troopers are recording a GPS latitude and longitude reading on the accident report form in addition to the information that they traditionally include. Based on their initial experiences, the officers have found the Magellan easier to use, but prefer the Trimble due in part to its greater sophistication. It should be noted that all four troopers are pilots and are, therefore, more comfortable with and knowledgeable about navigational equipment. Comparative results were not yet available on correlating latitude and longitude from the GPS with traditional milepoints. The Alaska Highway Department currently plans to redistribute them to other areas. Ultimately, they would like to install GPS receivers and antennas in all police and service vehicles, but perceive that it may take 15 years.

The Montgomery County, Maryland, Police Department currently is working with Fairchild Defense, a division of Fairchild Space and Defense Corporation, on a Tactical Emergency Action Mapping (TEAM) system. This will be a command and control system to support the efficient management of emergencies and incidents. The system will reflect a time-critical GIS application as opposed to a standard GIS application. Operators will be able to gain fast access to multiple scales of county maps, aerial photographs, and user-created overlay data bases. During the emergency, police vehicle locations can be tracked in real time via the GPS. As of June 1992, police vehicles had not been equipped with GPS receivers. The plans call for one "test" police cruiser to be instrumented within the next few months. However, the Montgomery County Police Department did not envision the application of this system to be used for routine traffic accidents.

APPLICATION OF GPS TECHNOLOGY TO ACCIDENT DATA COLLECTION

As a potential application to an accident data collection, GPS receivers can be installed in police enforcement vehicles or portable units can be provided to police officers. Upon arriving at the scene of an accident, the police officer can use the GPS receiver to determine the location of the accident. The officer can then record the latitude and longitude readings on the accident report form. Alternatively, if the police officer also has a computer, the reading obtained by the GPS receiver can be input directly into the computer through an RS-232 cable. The police officer could also use a computer that has internal GPS receiver capability. NAVSTAR has introduced a handheld combination GPS receiver and palmtop MS/DOS computer. Other GPS equipment and computer manufacturers are likely to follow with similar products. While GPS boards that can fit into a notebook or palmtop computer are currently not available, NAVSTAR recently introduced a 1-lb (0.4-kg), 13-in (330-mm) card that can be inserted into an IBM-PC (AT or XT version or similar PC-clone). The card can pick up signals from the NAVSTAR satellites and determine its position within approximately 49 ft (15 m). NovAtel also manufactures a GPS card that can be inserted in a laptop or desktop computer.

It should be clearly understood that additional location information is required to complement and supplement latitude and longitude readings. If latitude and longitude are the only pieces of location information on the accident report form, then the needs of many people that use accident reports, including drivers, insurance companies, and investigating officers who may need to appear later in court, will not be satisfied. Consequently, translation capabilities are required to convert the latitude and longitude back to a recognized location referencing system (e.g., road name or number, distance and direction from/to nearest crossroad or landmark, etc.). It is also important to note that GPS may not be available 100 percent of the time in all areas. Consequently, there will still be a need for a back-up location reference system.

The latitude and longitude measurements recorded from the GPS receiver are standardized, thus enabling a GIS to plot the locations of accidents. The combination of GPS and GIS will enable traffic engineers and safety analysts to identify locations associated with recurring accidents.

GPS receivers mounted in enforcement vehicles can also assist during the accident notification and response process. With a GIS, the dispatcher could automatically determine and identify the police cruiser closest to the reported location of the accident. A map of the area could be displayed on a data terminal in the police cruiser, thus allowing the police officer to navigate more quickly to the reported accident location.

Equipment Options

The product line for GPS receivers is evolving due to increasing commercial applications of GPS. There are a variety of handheld units, larger units that must be set up on tripods or other mounting devices, and units that can be permanently mounted to boats or vehicles. Some units require separate antennas; some units come with attached antennas. Trimble makes a GPS receiver that combines the antenna and receiver and is capable of doing internal differential processing. This unit can then transmit the corrected location directly through a cable connection to a computer. For the application of GPS for accident reporting, GPS receivers can be classified as either handheld units or invehicle units. Handheld devices, such as the Trimble Ensign, operate on four AA batteries and are the size of a handheld calculator. However, in a police environment, invehicle equipment is likely to be a preferred option. It should be considered that it can take several minutes for a GPS receiver to acquire a fix on enough satellites to arrive at a solution for a position. This problem would not occur in a unit that is installed and kept permanently operating by the vehicle battery.

The vehicle unit consists of a small receiver, approximately the size of a car radio, and a cone-shaped antenna. These items would need to be installed in the vehicle and connected to the vehicle's 12V line. The output of such a device is:

- Latitude.
- Longitude.
- Heading.
- Speed.

The data can be transmitted via an RS-232 connection to the appropriate computer where the information can be stored as the position of an accident or transmitted to the police dispatcher on a regular basis in order to report the vehicle's position.

If differential GPS is used, the correction signal from the base station can be sent as data to the GPS receiver over the police radio frequency data link. The GPS receiver would then use the modifications to produce a more accurate position. If the GPS receiver is kept on, the differential processing is performed instantaneously. There is no need to store the raw data for processing at a later time. Alternatively, the reference station's data could be stored continuously and the differential processing could be done at some time after the accident. For example, the officer could access a system data base at the end of his shift, obtain the reference station's correction data for the time that the accident was investigated, and then the adjustment could be calculated and the latitude and longitude could be corrected accordingly.

If GPS is also to be employed by the police agency as a component of an automatic vehicle tracking system, a map-based computer system is required at the central dispatcher. Equipment will be needed for the police vehicles to transmit their location data to the dispatcher. The central system is then required to decode the vehicle position data and any other relevant control data, such as vehicle status. The decoded data would then be displayed on a map on a computer screen for the dispatcher.

Implementation Costs

GPS receivers cost less than $1,000, regardless of differential vs. nondifferential or portable vs. stationary. Prices may be slightly less if the receiver is mounted in the vehicle, since an additional power supply may not be necessary. A reference locator for differential processing currently costs approximately $20,000. A data modem to transmit the data can be purchased for $700. The existing radio in the enforcement vehicle could also be used for this purpose. The installation would be approximately $400 per vehicle. No costs are included here for the computer as it is assumed that the computer that is used for the accident data recording would be capable of both tasks.

A map data base for a city with dispatching software would cost approximately in the range of $200,000 to $500,000, depending on the number of customized functions that are required and the extent of geocoding needed by the dispatcher.

Training

There would be minimal training requirements associated with this system. Police officers would need to be trained on how to operate the receiver, how to correctly read the values displayed on the receiver, and how to properly record the information on the accident report form. If the police officers are to use computers with appropriate software to create and generate completed accident report forms, then the officers will need to be trained on how to operate both the computer and the GPS receiver so that the vehicle position would be transferred electronically from the GPS unit to the computer and the data automatically recorded in the correct field. Police officers will also need training on how to modify the data on the computer if for some reason the receiver cannot be placed in close proximity to the point of impact for the accident. For example, the GPS receiver could be permanently mounted in the police vehicle. At the scene of the accident it may not be possible nor prudent to park the police vehicle in the exact spot where the accident occurred. Thus, it may be necessary to enter data such as "300 yd east of here," where "here" is provided by the GPS system, and software could modify the latitude and longitude reading. This would be necessary for States that utilize accident investigation sites on freeways and expressways.

In the case of using the GPS system as a reference location device, this process would be transparent to the officer as he/she would be required to do nothing. However, such systems usually include a status byte that is transmitted with the data. The status byte would be useful for vehicle tracking purposes. The police officer would be required to press a button on the computer in the police vehicle or select a menu option, etc. corresponding to the status of the police vehicle. The status byte and the location of the vehicle would be transmitted to the central dispatcher. The vehicle's location could be shown on a Geographic Information System with a particular color representing the status of the vehicle, which could show that the officer is:

- On routine patrol.
- Carrying a prisoner.
- Out of the vehicle.
- In need of backup.

- In need of an ambulance.

On a GIS, these status indicators are typically translated to colored arrows with numbers showing the vehicle identification.

Anticipated Benefits

Many of the benefits from improving accident location information were previously identified and described in the beginning of this chapter. For the traffic engineer who, among other things, must identify potentially hazardous conditions and accident prone locations on and off the highway system, accurate and reliable location information is extremely crucial. Too often law enforcement officers and those individuals who complete motor vehicle traffic accident report forms guess at distances or fail to note important landmarks or location references. Frequently, they misspell street and road names, use confusing route numbers, or fail to completely and properly provide location information on the form. The location data in statewide accident data bases are somewhat suspect and notoriously weak in terms of quality. Clearly, GPS provides enormous potential for rectifying this problem.

Limitations/Disadvantages

Limitations or disadvantages of a GPS system include the following:

- GPS receivers currently require a "sky-view" to obtain the signals from the satellites, unless a GPS receiver with dead-reckoning capabilities is being used. Location coordinates cannot be obtained in canyons, areas with tall buildings, and tunnels where a "sky-view" does not exist. However, the development of GPS receivers with internal solid state gyroscopes is underway and at least one manufacturer has such a product on the market, the Trimble Placer GPS/DR. These types of GPS receivers continue to generate latitude and longitude readings even in areas where the satellite signals are blocked.

- Handheld units are subject to misuse and neglect.

- Invehicle units require additional storage space.

- Very few existing location reference systems are based on latitude-longitude or x-y coordinates. Consequently, in order to utilize GPS, conversion software that translates the x-y coordinates into the existing location-reference system, or vice versa, is needed.

- The accuracy of a reading obtained with a GPS receiver when the Selective Availability feature is actuated is 328 ft (100 m). To improve the accuracy and overcome the signal distortion associated with SA, a differential GPS system is required. The cost to construct, operate, and maintain base stations that transmit correction signals to GPS receivers with internal differential processing capabilities can be expensive.

Alth
sign
futu

r
a
a

CHAPTER 7. PROMISING EMERGING TECHNOLOGIES FOR THE FUTURE

Although some may require additional development, the following "emerging" technologies have significant potential in terms of improving the accident data collection/reporting process in the future:

- Optical character recognition (OCR) software.
- Computers with voice input.
- "Smart" cards possibly used for payment of citations and to store driver records (revoked licenses, outstanding warrants, citations, convictions, accident history, etc.) that can then be accessed by police officers in the field.
- Automatic vehicle monitoring and tracking systems.
- Digital cameras.
- Field distance measurement devices for accident reconstructionists.
- Invehicle navigation systems.
- Driver/vehicle performance recording devices (e.g., "black boxes" similar to aircraft flight recorders) self-contained within vehicles.
- Improved automated incident detection systems.
- Heads-up displays in police vehicles.

Although the OCR, smart cards, and automatic vehicle location were mentioned earlier in this report, they are repeated in this section because they are still emerging and their potential to the accident data collection process has not been fully explored. The potential of these technologies are discussed in the following sections.

OPTICAL CHARACTER RECOGNITION

OCR software was briefly discussed within the context of form readers in chapter 3 and later discussed within the context of pen-based computers in chapter 4. It needs to be recognized that OCR software is still developing. Based on very limited experiences with software that is currently available, there are certainly limitations in its ability to recognize even carefully drawn block letters. Because the legibility of police officers' handwriting is often quite poor, there is genuine concern about the future effectiveness of technologies that rely on OCR. For a form reader system with OCR, the worst case would require clerical personnel to perform an extensive amount of editing or key-in alphanumeric information. The frustration level for police officers at the scene of an accident would be far greater if a pen-based computer is not accepting the officers' handwriting. However, the expectation is that the quality of optical character recognition software will improve with time. It may even be possible that the capabilities of OCR may reach a level that would recognize a very high percentage of people's handwriting. If or when that occurs, then pen-based computers and form readers will become much more attractive, not only in terms of cost but also in terms of effectiveness.

It is conceivable that OCR software could reach a level of development such that it could be used to extract data from the variety of State accident report forms that exist today. This would mean that the existing report form would not need to be changed. Software could then extract the handwritten text information from the graphic image to create a data base. It is important to note that OCR software is still in its infancy in terms of development. How much it grows in terms of capability and accuracy will depend to a large degree on the marketplace.

VOICE INPUT

The next level beyond having computers interpret a person's handwriting is having computers interpret spoken words. Voice input is made possible with voice recognition systems. The systems contain a vocabulary of up to several thousand words that are repeated back to the user as they are received from the user. There are two different types of voice recognition systems: speaker independent and speaker dependent. The first will allow input from any user and the second will recognize input from one user only. The unit uses a battery pack with a life of 8 hours and weighs approximately 5 lb (2.3 kg). This is a new technology, and the systems that are now available are high in price. However, it could be used by police officers in the field for accident data collection.

Unfortunately, the systems that feature voice input have several limitations. The state-of-the-art is such that it was not feasible to suggest that police officers can now use voice input systems to collect accident data and prepare accident reports. Current systems are susceptible to background noises and some noises can be mistakenly recognized as input. The current vocabulary may not be adequate to accommodate the wide range in names, addresses, vehicle descriptions, and a host of other information that must be recorded for an accident. Moreover, voice input systems are very expensive. As with optical character recognition, it is expected that voice input technology will continue to develop in the future.

SMART CARDS WITH DRIVER RECORDS

Smart cards were described in great detail as an identification technology for automating the collection of driver and vehicle information. However, the application described focused primarily on the use of smart cards for driver's licenses or for vehicle titles. For that application, the smart card would only contain selected information such as driver's license number, driver's name, address, date of birth, expiration date, and other information. It is not unreasonable to suggest that the smart card could also contain data on driving records. Police officers do not in all cases call in a driver's license check at the scene at the accident or, for that matter, for a routine traffic stop. If the smart card has the driver's entire record, then the police officer may not need to run a check. Certainly, from the perspective of safety, it would be highly desirable to accurately identify chronic or habitual problem drivers and get them off the road. In the future, smart cards with their radio frequency capabilities may assist the police officer in achieving that objective. Alternatively, smart cards have also been used for payment of transit fares. It certainly would be appealing to the local enforcement and criminal prosecutors to collect payment from drivers at the time they are stopped.

AUTOMATIC VEHICLE MONITORING AND TRACKING SYSTEMS

This topic was briefly touched in the discussion of location technologies. With improved monitoring and tracking of the location of police vehicles and emergency vehicles, response times to accidents could be reduced. If the dispatcher knew and could see the location and status of all police vehicles in a given area on a computer screen, then police resources could be utilized more efficiently in response to a report of a traffic accident. Alternatively, if the coordinates of the police vehicle could be displayed to the dispatcher, then the dispatcher could relay these coordinates over voice or data radio frequency link. The police officer could then record these coordinates on the accident report form.

DIGITAL CAMERAS

Digital camera technology is relatively new. Digital cameras convert the analog light sources usually captured on film into digital electronics inside the camera itself (using technology similar to that used in scanners). The image is stored on a small magnetic disk or in memory, which takes the place of film and requires no processing. The digital cameras researched are able to store a maximum of 32 pictures. The pictures can be downloaded using an RS-232 cable into a computer. Then, they can be selected and retouched (if needed) using a graphics program supporting the digitized picture format. The digitized pictures can then be imported into other applications for further processing. Some digital camera packages include graphics software that allow the user to edit the digitized pictures. Some digital cameras include an automatic flash, thus enabling pictures to be taken indoors or outdoors. Digital cameras have been used for a number of applications, including real estate, emergency services, training manuals, and catalog production. Digital cameras also have the potential for personnel data bases, identification badges, and inventory control applications.

The use of digital cameras can be an efficient means of collecting critical data at the scene of an accident in a timely manner. Many times, clearing the scene of an accident to free traffic is more important than obtaining complete accident information. The use of a digital camera allows the officer to take pictures quickly, as opposed to drawing a sketch of the accident scene. The pictures taken with a digital camera can be downloaded to a computer (using a cable) and analyzed at a later time to determine other accident characteristics, such as:

- Speed and direction of the vehicles involved (through skid marks).
- First impact (through the location of glass or other debris on the roadway).

- Property damage (useful for insurance companies).

- Sequence of events.

It is also possible that post-processing software could be developed to assist in the analysis of the physical evidence for accident reconstruction. Digital cameras can also reduce the likelihood of errors and incomplete data, which can occur with hand-drawn sketches or when relying on the officer's memory of the accident to complete an accident report at a later time. Note that the development of a hand-drawn sketch of a multiple-vehicle accident may require several hours of the officer's time. More importantly, images can be transmitted via modems from the accident site to other locations such as accident reconstruction teams. This represents a significant improvement over the use of conventional cameras.

Digital cameras are helpful in maintaining a complete record of the accident. This information may be useful at a later time by safety analysts and traffic engineers. It is possible that the graphic images produced by a digital camera can be consolidated into a data base with other accident information that can be extracted or viewed through a Geographic Information System. It is possible that pictures taken by digital cameras can also be used for legal purposes. In court, these pictures can provide proof of the events that actually occurred.

Digital cameras may not be required for all types of accidents. It is possible that the benefit of digital cameras will only be realized during severe accidents or other types of accidents involving several vehicles (possible in a wide area). Currently, accident reconstructionists use still cameras to take pictures of the accident scene. It is likely that these users can benefit from digital camera technology. However, the use of digital cameras must be tested during adverse weather conditions and at nighttime, where minimal light exists. It remains to be seen if the pictures produced during these conditions will be useful.

Due to the large amount of disk space needed to maintain and store the images produced by digital cameras, high-capacity hard disks or optical disks may be required. More disk space will be required as digital cameras are developed to produce higher resolution images. Digital cameras that are currently available range in price from $400 to $2,000.

DISTANCE MEASUREMENT DEVICES FOR ACCIDENT RECONSTRUCTIONISTS

During this project, several police officers who are certified accident reconstructionists indicated a pressing need for technology that can reduce the time it takes to obtain field measurements and create accurate plan drawings of the accident scene. The accident reconstructions indicated that a majority of the time that they spend in the field is devoted to collecting field measurements using both measuring wheels and measuring tapes to create the base drawing. The process is tedious and time consuming. Depending on traffic flows and geometric conditions, the police officer may be at risk while he obtains the measurements. For many accident investigations, at least one lane has to be closed to traffic, and sometimes the entire roadway has to be temporarily closed. Depending on the traffic flows during this time, traffic queues can grow to be several miles long and motorists can experience substantial delays. The Washington State Department of Transportation recently completed an evaluation of using portable surveying equipment to automate the time-consuming process of collecting detailed field measurements for accident reconstruction purposes. The evaluation found that using total work stations to conduct an accident investigation of a serious accident required only 46 percent as much time as was required for an investigation using tape measurements. Moreover, the study found that the cost for a workstation, which is in the $15,000 to $20,000, range would be recovered in terms of reduced delay and wasted fuel the first time it is used at an accident scene.[7]

In addition to improved devices to collect measurements in the field, the ability to access a detailed GIS system from the field and "call up" base plan drawings at the scene would be highly desirable. To automate this collection of field measurements would greatly reduce time to the officer, delays to the motoring public, and traffic disruption costs.

ADVANCED INVEHICLE NAVIGATION SYSTEMS

Advanced invehicle navigation systems represent one new technology that should enable police officers to locate and travel to accident sites in a shorter time period. This technology has been marketed for the fleet management industry and is not restricted solely to police vehicles or emergency vehicles. Some systems utilize new hardware mounted in the police vehicle. The commercially available Blaupunkt TravelPilot is an invehicle console that displays a dynamic street map showing the vehicle's present position and the destination provided by the dispatch center. The map reflects the vehicle's movement, showing a heading-up picture of the road network. The driver is also able to select the appropriate map scale. The TravelPilot, when integrated with a communications and CAD system, maintains a critical link with the dispatch center, sending updates on vehicle location and status as well as displaying all incoming map information and text messages to the driver. For vehicles that already have invehicle MDT's or computer hardware, invehicle map displays and software can be created without the need for additional hardware. Etak is a major source of digital road maps. EtakMap data bases have the coordinate accuracy and street network content of 1:24,000 scale U.S. Geologic Survey quad maps and can be used as a base street network file for CAD vendors building a geofile or for developers of a local Geographic Information System (GIS). In addition, these invehicle navigation systems can be integrated with or make use of the Global Positioning System (GPS). The Los Angeles Fire Department is one of Etak's major customers.

BLACK BOX RECORDERS FOR AUTOMOBILES

Invehicle black box technology has significant potential for enhancing vehicle safety by providing accurate and complete information regarding driver or vehicle actions prior to and during an accident. There are no known applications of black box technology in private vehicles to date. There have been attempts to employ black box technology for monitoring of commercial vehicles, but these have not met with general acceptance and are limited in scope to monitoring speed or miles traveled.

Given the current state of vehicular technology, it is feasible to develop prototype monitoring and recording devices that can collect data regarding the status of critical vehicle components, vehicle speed, vehicle direction, turning movements, weather conditions, driver condition, and driver actions. For example, automakers are considering, and in some cases have deployed, vehicle communication networks that provide a standard means for devices installed in the vehicle to communicate. This approach could be used to record data from various systems in a black box device.

The following scenario could be achieved:

- A vehicle is equipped with advanced driver information systems and advanced vehicle monitoring systems as well as an invehicle local area network (LAN).

- The status of all major vehicle systems including brakes, tires, engine, and lights is transmitted over the LAN to the black box. Driver convenience devices such as climate control, cellular phone, and navigation system are also linked to the LAN.

- A tire blows out, causing the vehicle to swerve and collide with a retaining wall.

- The monitoring system reports a sudden loss of tire pressure and at the same time, a sudden change in direction and speed are recorded, as is a violent steering movement. The deployment of the driver airbag is also recorded before the electrical system fails as a result of the collision.

- All of these data plus various normal information, such as the fact that the telephone was in use, are recorded by the black box device.

- The investigating officer locates the black box in a standard location and connects the investigation recording computer to the black box to transfer the data that will become a part of the official accident record.

This scenario is entirely feasible using existing technology. General Motors has installed a communication network in some of its vehicles. Currently, it is used for communications between steering wheel-mounted controls and intelligent climate control and radio devices mounted in the conventional dashboard location. The vehicles being used for the TravTek Intelligent Vehicle Highway System project have this feature plus computers and a display for vehicle navigation and directory functions. There is also a link to the vehicle's telephone for automatically dialing an establishment listed in the onboard directory.

Black box technology has been proven in aircraft use. Automotive units would not require the same level of protection as aircraft units, which may lower the cost. Many automobiles already have monitoring systems for critical components that can be connected to a black box. However, a barrier for use in automobiles is cost. Consumers must perceive a personal benefit before they are willing to pay for additional devices. Reduced insurance costs might provide an incentive. If black box devices can be produced inexpensively, they might be mandated for use by legislation. Another possible barrier is legal entanglements. Right-to-privacy laws might be invoked by those who perceive the recording of such information as an invasion of privacy.

HEADS-UP DISPLAY

Heads-up display is a process whereby an image of a display is projected to appear as a virtual image in the line of sight of the operator. An image is created at the light source as shown in figure 24. This image is projected by a series of lenses and mirrors onto the windshield. A virtual image of the display appears to the driver to be floating in space at approximately the position of the front bumper. Any type of image can be displayed. Some designs under study by the motor manufacturers include speedometers which are permanently displayed and indicator lights, such as turn signal and engine warning lights, that are displayed when they illuminate.

Heads-up display technology is not new. In the Second World War, the later versions of the Spitfire fighter plane (approximately 1944) used a heads-up display as the gun sight. It is through aircraft fighter technology that these types of displays have been developed. Motor vehicle manufacturers are currently researching into these devices. There are prototype versions in General Motors (GM) cars developed by Hughes Aircraft (owned by GM).

The application of this technology to accident data collection is limited. For most cases, the major benefit of the heads-up display is to allow drivers to obtain and read information while driving. In contrast, most accident data collection takes place while the police cruiser is parked. However, there may be potential future applications as the technology becomes more fully developed. For example, images recorded by closed circuit surveillance cameras on a freeway could be presented as a heads-up display to a police officer responding to a report of an

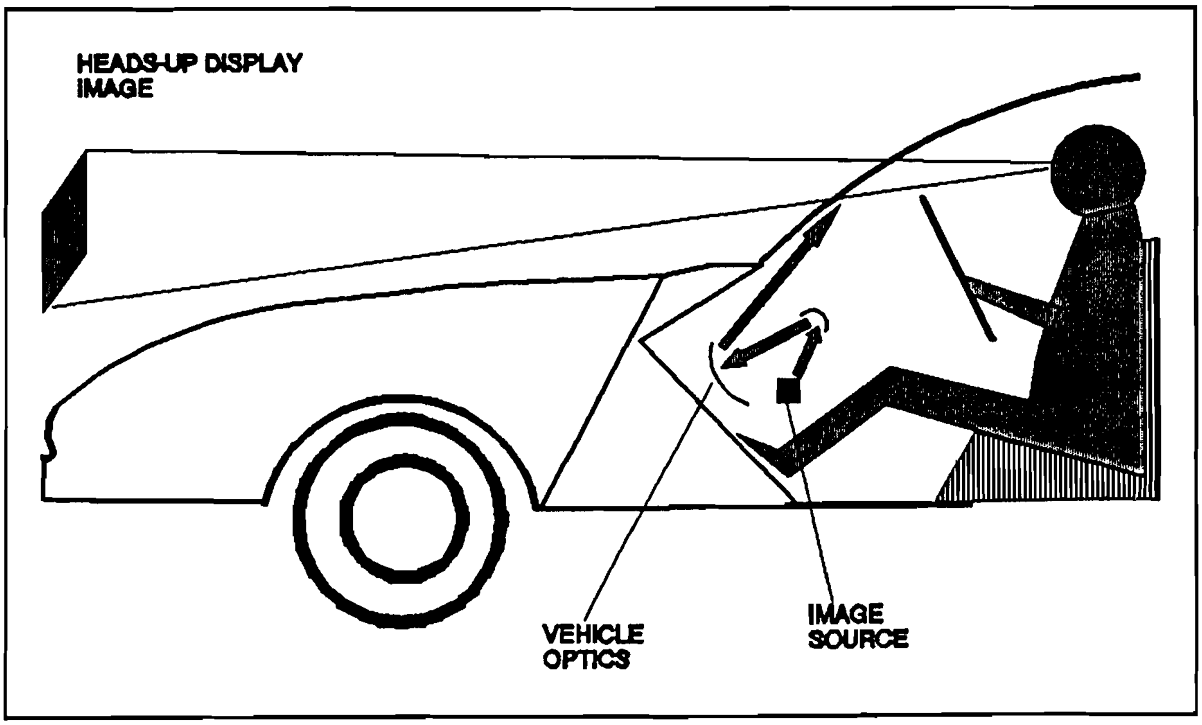


Figure 24. Heads-up display.

accident. The image may help the officer determine how he needs to render assistance, stabilize the scene, and report the accident before he arrives. In fact, it could help him select the optimum location to park his vehicle and investigate the accident.

IMPROVED AUTOMATED INCIDENT DETECTION SYSTEMS

While it was deemed to be outside the scope of this research project, the topic of improved accident detection deserves to be included in this chapter on emerging technologies that can further improve accident data collection in the future. As was stated in the introduction in chapter 1, a major concern of the Federal Highway Administration relevant to this project was the congestion-causing effect of accidents on heavily traveled highways, especially in the urban areas. Most of the discussion in this report focused on the process that transpires after the police officer arrives on the scene. Traffic disruption costs and delays resulting from accidents can be substantially reduced if the occurrence of an accident can be detected sooner. Response times can be reduced. The appropriate personnel and equipment can be dispatched much sooner to the accident site. While freeway surveillance and control systems and traffic-responsive signal systems have existed for many years, the Intermodal Surface Transportation Efficiency Act (ISTEA) has placed a spotlight on the potential for Intelligent Vehicle Highway Systems and particularly the role of advanced traffic management systems to address the evergrowing urban congestion problems. There are numerous research studies underway that are attempting to improve the capability of highway and other agencies to detect and respond to traffic incidents.

CHAPTER 8. SUMMARY

The Federal Highway Administration (FHWA) has been and continues to be concerned with the quality of motor vehicle traffic accident data that becomes available to the highway safety analyst/traffic engineer at the State or local level. The FHWA is concerned that the quality, completeness, and timeliness of these data may not be adequate to promote the systematic analysis of motor vehicle traffic accidents, the identification of locations with unusually high accident occurrence, the evaluation of accident reduction programs, and the continued surveillance of the highway system. In addition, the FHWA is equally concerned with the adverse impact that motor vehicle traffic accidents have on traffic flow and air quality, especially on urban freeways and arterials. It has been estimated that 60 to 65 percent of the delay experienced in an urban area is attributable to nonrecurring incidents that include traffic accidents. The expedient collection of accident data may be a potential mitigation measure to reduce nonrecurrent congestion.

DEFICIENCIES WITH THE CURRENT ACCIDENT DATA COLLECTION PROCESS

There are numerous deficiencies and problems associated with the current accident data collection process. These include the following:

- Administrative/Staffing problems - Inadequate funding and/or personnel is a frequently repeated problem. The contention is that the designated State agency does not have the resources to adequately process the extremely large numbers of report forms. In some States, there are additional demands on the State data center personnel imposed by additional report forms (i.e., forms required to be completed by drivers) or nonstandard forms used by selected cities or agencies. In addition, many police officers have a less than optimum attitude towards accident data collection.

- Timeliness problems - There is often a delay between when the accident occurs and when the report is received by the central agency. There is also a considerable time lag between when the accident report form arrives at the State data center and when it is key-entered into the data base. The total time lag can exceed several months.

- Legibility problems - Completing a handwritten form in a hurried manner under less than ideal conditions contributes to the poor legibility of many accident reports. Illegible reports pose substantial obstacles to data coders and keypunchers.

- Incomplete reports and missing data problems - The amount of missing data varies considerably among variables as well as across States. It is estimated that the VIN is missing for as many as 40 to 50 percent of the completed reports. Missing data may range from 0 to 10 percent for any other variable within a given State. In addition, reports are often submitted with no collision diagram and/or narrative.

- Errors, inconsistencies and data problems - The magnitude of erroneous data in the accident records data base varies, depending on the practices, procedures, and policies of the State. Many data elements are questionable because they require the reporting officer to make judgments (e.g., restraint use, injury severity, alcohol and drug involvement, contributing factors/causes, etc.). Factual data related to the driver, vehicle, and the location are often erroneously recorded or entered in the data base. In addition, narratives and sketches are often inadequate for highway safety analysis.

Many of these and other problems could be eliminated through the use of new and emerging technologies for the collection and processing of motor vehicle accidents. These technologies were identified in previous chapters and are summarized and evaluated here.

POTENTIALLY APPLICABLE TECHNOLOGIES

It should be clearly understood that changes in procedures and training can yield improvements with respect to both the preparation of accident reports by police officers and the processing of accident data by State personnel at the State data center. For example, the development and distribution of better guidelines for recording accident location could produce an improvement in the quality of location data. Improved training, the production and distribution of training videos, remedial training, and periodic awareness sessions could also result in improved quality and legibility of accident reports. However, there is a limit to the improvements that can be gained through aggressive campaigns to promote quality and accuracy in preparing accident reports and developing accident records. For example, police will still be required to spend the time to record all the necessary data on an accident report form. Coders will still be needed to review and code selected data elements on the report. Data entry personnel will still need to key-enter data from the form. All these human activities take time and are prone to error.

The application of new and emerging technology has the potential to yield even greater improvements to the data collection process. Technology can be applied to reduce the time it takes for a police officer to complete an accident report, improve the timeliness of accident data, reduce the demand and costs associated with data processing personnel, and improve the quality of accident data. It must be recognized, though, that the application of a technology is not a panacea. The application may reduce the magnitude of one particular problem, but it may create other issues and problems. Technologies that could be applied today to the accident data collection process include the following:

- Optical scanner and form reader systems that feature optical mark sensing, optical character recognition, and/or image storage capabilities.

- Portable computers, including laptops, notebooks, and pen-based clipboards.

- Advanced location technologies including Global Positioning System (GPS).

- Identification technologies such as magnetic stripe, bar codes, and smart cards.

REVISED ACCIDENT REPORT FORMS AND FORM READERS

Technologies such as form readers and optical scanners can be applied to improve the processing of accident reports at the State data center. There are basically four implementation scenarios:

1. Implement an optical scanning system that creates and stores digital images of accident reports.

2. Revise the State accident report form so that it can be "mark sensed" and implement a form reader system with mark sensing capability that interprets selected data on the form and creates a record of these data for the State computer-based accident records system.

3. Revise the State accident report form and implement a form reader system that employs both mark sensing and optical character recognition to extract data from the completed accident report form.

4. Revise the State accident report form for block lettered text input and implement a form reader system that employs mark sensing and optical character recognition to extract data from the completed accident report form <u>and</u> stores digital images of the accident reports.

The major benefits of the first scenario is the increased accessibility of hard copies of individual accident reports and improved management of the paper accident report files. While this application can replace microfilming, it would not reduce costs for data coding or data key-entry. State personnel would still need to perform those functions. Also, this first scenario would not reduce the police officer's time to complete an accident report, would not reduce motorist delays resulting from accidents, and is not likely to achieve a significant improvement in timeliness or the quality of the data in the accident records data base.

The other three scenarios would produce improvements in the timeliness and quality of the data in the accident records data base and would reduce the demands and/or costs for coding and key entry of accident data. However, they all require a major revision to the format of the State accident report. Care needs to be exercised in devising a new report form to satisfy the needs of multiple users, not just accident data processing personnel at the State data center. Space requirements for mark sensing or optical character recognition may constrain the form, but in no case should either the narrative or the sketch be dropped. These provide vital information to safety analysts, highway safety researchers, and traffic engineers, and therefore space should be reserved for both of them on the form. In addition, the introduction of a vastly revised accident report form must be accompanied by improved training and by marketing the benefits of the new report form.

The second scenario would reduce the demand on State personnel at the central State accident data processing center and may reduce the costs associated with coding and keypunching, depending on the current State practices. This system has been adopted recently in Michigan. With their revised form, the police fill in the appropriate circle for selected data elements. The form is scanned, using mark sensing technology, to extract selected data from the form into an accident records data base. Other data on the form (e.g., driver's names, addresses, etc.) is key-entered by State personnel and merged with data that was mark sensed to create a complete record.

The third scenario attempts to build on the second by utilizing optical character recognition (OCR) software to capture text information for those data elements that cannot be easily converted to mark sensed fields. This scenario has not, as yet, been applied for accident data processing. In order to implement it, the accident report form would require text to be entered in standardized block letters in specific spaces on the form. Hence, there are space limitations. One of the major drawbacks is the quality of currently available OCR software to recognize multiple styles of handwritten characters. The state-of-the-art is currently inadequate to interpret handwritten information on existing accident report forms. Even with continuing improvements, it is not likely to be able to read handwriting without reformatting the accident report form. Despite these limitations, this scenario is appealing in its potential to maximize the automated extraction of data from completed accident report forms and minimize personnel costs for data coding and keypunching. Costs for form reader systems with OCR software that are commercially available range from $100,000 to $250,000.

The fourth scenario combines the features of the first and third scenarios. Not only would the maximum amount of data be extracted by automated methods from completed accident report forms, but digital images of the complete form including both the narrative and the sketch would be stored. Thus, the narratives and sketches could be easily accessed.

PORTABLE COMPUTERS

Portable computer technology such as laptops, notebooks, and pen-based computers can be used by police officers to capture the data at the scene of the accident in an electronic medium. Software can be developed to create entry forms for police officers to use to enter data for the accident. The software can also be used to generate hard copies of accident reports. The accident data can then be transmitted to the State data center in electronic media, thereby reducing the costs incurred by the State to code and/or key-enter this data.

There are a variety of computers currently available that could be used by police officers at the accident scene. Laptop, notebook, and pen-based computers were identified as feasible instruments for accident reporting. Handheld or palmtop computers were judged to be inadequate for accident reporting since the accident report form requires too much data entry to be performed quickly and easily on a palmtop. Laptop and notebook computers share many common characteristics, with the notebook computer being a lighter and slightly smaller version of the laptop. Laptops and notebooks can be easily programmed to be used in the field. The basic design of these computers lend themselves to use within the security of the police vehicle.

Whereas data is entered via a keyboard on a laptop and notebook, pen-based computers with OCR software would allow police officers to write information by hand that would be entered into the data field. As with the form reader systems with OCR, the current capability to recognize characters, numbers, and letters handwritten by a variety of multiple users of the OCR software is limited. Yet, pen input supplemented with a keyboard offers the most promise.

There are a wide variety of scenarios to implement portable computers, including those shown in able 4.

Table 4. Implementation scenarios for portable computers.

	USE AS A REPORT CREATION INSTRUMENT	TO BE USED AS AN MDT WITHIN A CAD	WITH INTEGRATED CAPABILITIES TO READ BAR CODES/MAG STRIPES	WITH INTEGRATED LOCATION TECHNOLOGY (GPS)
1	Accident Report Only	No	No	No
2	Accident Report Only	No	No	Yes
3	Accident Report Only	No	Yes	No
4	Accident Report Only	No	Yes	Yes
5	Accident Report Only	Yes	No	No
6	Accident Report Only	Yes	No	Yes
7	Accident Report Only	Yes	Yes	No
8	Accident Report Only	Yes	Yes	Yes
9	All Reports	No	No	No
10	All Reports	No	No	Yes
11	All Reports	No	Yes	No
12	All Reports	No	Yes	Yes
13	All Reports	Yes	No	No
14	All Reports	Yes	No	Yes
15	All Reports	Yes	Yes	No
16	All Reports	Yes	Yes	Yes

Several key decisions affect how the computers will be used and the type of computers to be purchased. To maximize their utility and subsequent attractiveness to police agencies, portable computers should be used for all police reports, including the accident report. From the police agency management's perspective, the purchase and use of a portable computer solely for accident reporting is not likely to be cost-effective. More and more police agencies throughout the United States are implementing computer-aided dispatch (CAD) systems. These systems allow greater "community policing." Messages can be sent over police radio frequencies to the MDT and are read by the officer upon returning to the vehicle. Several police agencies, including San Jose (CA) and West Palm Beach (FL), are currently evaluating the potential for a pen-based computer to serve the dual roles of MDT and an instrument for data collection and report preparation. As more and more States begin to use magnetic stripes on driver's license and/or bar codes on vehicles, it may be desirable to purchase a computer with integrated capabilities. For example, a magnetic stripe reader can be built into a portable computer. The pen for several pen-based computers currently available can also function as bar-code wand scanner. Alternatively, if location data is a major problem, or if the police agency is considering a automated vehicle tracking system, then it may be desirable to investigate emerging computer products that have internal GPS capability.

LOCATION TECHNOLOGIES

Technologies exist that could be applied to improve the accuracy of location information. Several were examined for this study. While it has been suggested that cellular telephone networks could be used for location determination, there are few systems that are in place or under evaluation that could be readily applied to accident reporting. Loran-C, which relies on radio frequency triangulation, is not available in all areas of the country. While Loran-C has been successfully used in the shipping and industries and for boating for a number of years, its application to land-based vehicles have been limited. Systems that rely on dead reckoning and map-matching logic show great promise. Basically, the system is self-contained within the vehicle and does not rely on the reception of any satellite or radio frequency signal from outside the vehicle. Systems that are currently available require a fair amount of space in the vehicle and trunk and are costly. To equip all police vehicles for the purposes of improved accident location may be cost prohibitive. Since it is not likely that all police agencies in the State will implement these systems, its effect on the quality of the location data would be localized. The Global Positioning System (GPS) appears, on the basis of this assessment, to offer the greatest potential for improving the quality of location information for accident reporting and reducing the costs to the State and possibly the police agencies for processing and coding accident data.

GPS was developed and is operated by the U.S. Department of Defense. GPS is based on a constellation of ultimately 24 NAVSTAR (Navigation Satellite for Timing and Ranging) satellites orbiting the Earth in 12-hour orbits. Each GPS satellite continuously broadcasts two signals: a C/A-code signal for worldwide civilian use and a P-code signal for U.S. military use only. On Earth, GPS receivers collect the radio signals and internally calculate the user's location based on a set of simultaneous measurements of distance to three or more satellites and the associated time delay. Three satellites are required for two-dimensional positioning (latitude and longitude), and four satellites are required for three-dimensional positioning (latitude, longitude, and altitude). Since GPS receivers passively acquire the satellite signals, the number of GPS users is unlimited. However, while not affected by factors such as weather, geographic location, or electrical interference, reception of GPS signals can be adversely affected or even lost in canyons of tall buildings or in tunnels. There are new GPS devices about to come on the market that utilize solid state gyroscopes that could overcome this deficiency.

Currently, a C/A-code GPS receiver can provide position information with an error of less than 82 ft (25 m) and velocity information with an error of less than 1.6 ft/s (0.5 m/s). However, the U.S. Department of Defense implemented a policy known as Selective Availability (SA) in the fall of 1991. Random errors are inserted into the system to reduce the GPS C/A-code position accuracy to 328 ft (100 m) horizontally and 512 ft (156 m) vertically. A technique called differential GPS (DGPS) overcomes the effects of Selective Availability and also provides increased overall accuracy. Under differential GPS, one or more GPS receivers are placed at precisely known locations. The known position information is compared with the reading obtained from the GPS receiver at that location. The difference is then used to calculate corrections for the GPS signal. The error corrections can then be communicated via radio frequency or data link to other specially equipped receivers in the area. The resulting accuracy is 7 ft (2 m) horizontally and 16 ft (5 m) vertically, although there are some expensive differential receivers that can improve accuracy to within centimeters.

There are a variety of scenarios in which to apply GPS technology to the accident data collection process, including the following:

1. Install GPS receivers in police enforcement vehicles or provide portable units to police officers. Request the officer to record the latitude and longitude readings on the accident report form.

2. Provide police officers with GPS receivers and portable computers that have the accident reporting software. The reading obtained by the GPS receiver can be input directly into the computer through an RS-232 cable.

3. Provide police officers with computers that have the accident reporting software and internal GPS receiver capability.

Since GPS receivers provide coordinate data, Geographic Information Systems (GIS) can be developed and applied to easily plot the locations of accidents. The combination of GPS and GIS will enable traffic engineers and safety analysts to search for and identify locations exhibiting certain accident characteristics. However, it should be clearly understood that location information that is currently being gathered may be required to complement and supplement latitude and longitude readings. It is also important to note that GPS may not be available 100 percent of the time in all areas. Consequently, there will still be a need for a back-up location reference system.

GPS receivers are evolving as the number of commercial applications of GPS increases. There are a variety of handheld units, larger units that must be set up on tripods or other mounting devices, and units that can be permanently mounted to boats or vehicles. Some units require separate antennas; some units come with attached antennas. The invehicle unit consists of a small receiver, which is approximately the size of a car radio and can be connected to the vehicle's 12V line, and a cone-shaped antenna. The outputs of a GPS receiver are generally latitude, longitude, heading, and speed. GPS receivers cost less than $1,000, regardless of whether or not they have internal differential processing capability or are portable or stationary. The unit cost to install the GPS receiver and additional peripheral equipment for data transmission (e.g., radio communications hardware that relays the position of a vehicle equipped with a GPS receiver to a central dispatcher) in a vehicle would be approximately $400 to $1,100. A reference locator for differential processing currently costs approximately $20,000.

The benefits accruing from improved accident location with GPS receivers will vary, depending on the quality of current location correction methods. Consequently, the cost may not always be greater than the benefits. Police agencies should be aware that there are many other uses for GPS. The devices can be used as location devices for purposes other than reporting location on an accident report form. In addition, GPS receivers mounted in enforcement vehicles can also be implemented to serve as vital components of a real-time automated location system. This would allow the police dispatcher to monitor and track police vehicles, which could produce improvements in officer safety and response time to accidents and other incidents, among other factors.

IDENTIFICATION TECHNOLOGIES

The collection of driver and vehicle data can be further automated if drivers have an identification technology and the police officer at the scene of the accident has the technology that can read and store the data. The implementation of this technology should produce an improvement in the quality of driver and vehicle identification information (e.g., name, address, date of birth, vehicle make, model, year, VIN, etc.). Police officers would not have to key-enter the extensive amount of information. Thus, errors ranging from missing data to typographical mistakes should be minimized. In addition, it should take far less time for police officers to complete a report because they will not have to key-enter the data. Identification technologies include the following:

- Driver's licenses with magnetic stripes.
- Driver's licenses with bar codes.
- "Smart" card driver's licenses with embedded radio frequency chips.
- Vehicle registration cards or title cards with magnetic stripes.
- Vehicle registration cards or title cards with bar codes.
- Smart card registration or title cards with embedded radio frequency chips.
- A bar code mounted in or on the vehicles.
- A smart card mounted in or on the vehicle.

In all likelihood, the identification technology will be implemented by the driver's licensing division or vehicle registration division of the State's department of motor vehicles. Hence, State and local police officers will be able to capture identification information only after the State begins to issue smart cards, driver's licenses with magnetic stripes or bar codes, or vehicle registration/title cards with magnetic stripes or bar codes. California has been issuing driver's licenses with magnetic stripes since 1991. New York, Virginia, and New Hampshire have or soon will be issuing driver's licenses with magnetic stripes. New Mexico, Illinois, Indiana, and Maryland are currently examining the feasibility of magnetic stripes on driver's licenses.

To read encoded data from the magnetic stripes on driver's licenses, police must be equipped with a computer and a magnetic stripe reader system. Some manufacturers provide a magnetic stripe scanner unit connected to a decoder unit via a cable, whereas other manufacturers have developed the decoder and magnetic stripe reader as one integrated unit. Decoders are useful in that they can support input from magnetic stripe readers and bar-code scanners. Magnetic stripe readers can be connected directly to the computer through an RS-232 serial port without modification to existing hardware, provided an RS-232 serial port is available. If the computer does not have an integrated keyboard (e.g., such as laptops and notebooks), then the magnetic stripe reader can also be connected to the keyboard to act as a keyboard emulator. The average price for a complete magnetic stripe reader system with a decoder unit is approximately $400 to $850. The battery in the enforcement vehicle may be used as a power supply for the magnetic stripe system.

Similarly, portable bar-code scanners can also be purchased and added to a portable computer. Portable bar-code scanners include wands, charged coupled device (CCD) scanners, laser beam readers, and slot readers. Wands, which typically look like fat marking pencils, must touch the coded surface. They cost approximately $400 without a decoder unit. These wands can also be integrated with the pen instrument for pen-based computers. Charged coupled device (CCD) scanners, which are usually in the shape of a gun, photograph the bar code, converting the optical image into an electrical image. CCD scanners do not require contact with the bar-code label, but the maximum scanning distance is approximately 1 in (25 mm) from the label and a maximum label width is only approximately 2.5 in (64 mm). CCD scanners, which are more expensive than slot readers and wands, cost approximately $700 per unit without a decoder unit. Laser scanners, which are also usually in the shape of a gun, are generally the most expensive type of input device with a unit price on the order of $1,250 without a decoder unit. Laser scanners also do not require contact with the bar-code label and are useful when the coded surface to be read is at a distance of 2 to 18 in (51 to 457 mm) from the scanner. This makes it ideal for reading the VIN through the windshield. However, the laser scanner is also the least durable of the four types of portable bar-code readers since it is an electro-mechanical device with moving parts. Slot readers are designed for reading identification cards with bar codes that are run through the slot. With a slot reader, the bar codes must be positioned accurately on the identification card. The cost of a bar-code slot reader with the decoder unit is on the order of $600. The addition of a decoder unit for a bar-code wand, CCD, or laser scanner would increase the unit price by approximately $100 to $400. Finally, it is important to recognize that some bar-code readers are not compatible with all bar-code symbologies. Accessories such as an input device holder, extension cables for the input device, and a power supply are available.

Smart card readers can also be used as peripheral equipment for laptop, notebook, and pen-based clipboard computers. A smart card reader, which is designed to house a smart card and is about the size of a calculator, could be installed in the police vehicle. The smart card reader could be connected to the computer system in the enforcement vehicle through an RS-232 serial port. To integrate this data read by a smart card reader would require the development of customized software. This differs from bar-code and magnetic stripe readers, which act as a keyboard interface and do not require any software modifications to the computerized accident form. A complete portable reader system currently costs approximately $5,000; however, some manufacturers offer quantity discounts.

FORM READERS VS. COMPUTERS

In a certain sense, the application of form reader technologies can be compared directly with the application in which police officers are provided portable computers for collecting accident data. Both applications attempt to achieve the following objectives:

- Improve the timeliness of accident data.
- Reduce data input errors and omissions.
- Reduce the central agency's costs for coding and keypunching.
- Reduce demands on report processing personnel at central agency.
- Improve information management and accessibility of accident data.
- Improve the overall quality of all data elements.

Compared to the use of portable computers by police officers, the application of a form reader system is appealing because the technology can be implemented by the State agency responsible for the accident report and accident records systems. It does not require all State and local police agencies to purchase additional hardware or learn to use new equipment. In addition, the application produces benefits to the agency that have incurred the costs. Moreover, this form reader application is likely to be significantly lower in terms of initial implementation costs. The system costs of the form reader equipment is on the order of $75,000 to $250,000. There will also be costs for the development and pilot testing of a new report form, training of both data processing personnel and police, production and distribution of new report forms throughout the State, software, and system support. However, depending on how many police agencies in the State currently have or can gain access to portable computers, the cost incurred by both the State and local police agencies to purchase the sufficient number of portable computers at anywhere from $1,800 to $8,000 per computer can be staggering. Even if the State agency contributes a minimal amount towards the purchase of needed new computers, the State agency will incur costs to develop, test, and debug the software. In addition, the State agency will need to revise procedures and possibly modify equipment to accept accident data in electronic media and develop procedures to support the software and users of the software. Perhaps the most daunting obstacle is that the success of the use of computers to capture accident data depend on the cooperation of numerous police agencies.

While the obstacles of cost and police cooperation may appear large, the use of computers by police officers offer additional benefits compared to the form reader application previously described. Because the police officers would capture all data elements that could be submitted to the central agency on electronic media (e.g., floppy diskettes), this would significantly reduce the cost to code and keypunch data at the central agency. It is also important to recognize that benefits are accrued if computers are used by only a percentage of the police agencies in the State. While it would be desirable, it is not necessary for all State and local police agencies to purchase and use portable computers for accident reporting. Additional benefits related to the accident data collection process that are expected to result from the use of portable computers include the following:

- Improved legibility of accident reports.
- Improved timeliness of accident data.
- Improved overall quality of all accident data elements.

- Reductions in the time for an officer to complete an accident report.
- Reductions in the time that traffic is affected by an accident.
- Reduction in data input errors and omissions.
- Reduction in the demands on State data processing personnel.
- Improved information management and accessibility of accident data.

The extent of these improvements and reductions will depend greatly upon the individual State or local municipality. This is especially true with respect to missing, erroneous, and inconsistent data. Moreover, the State and local police agencies will be in a position to further exploit the capabilities of the computers and reap substantial additional benefits. Software could be developed and made available as shareware to automate the preparation of all police reports, including incidents, burglaries, robberies, homicides, etc. Some local police departments who have implemented portable computers have accrued benefits in terms of improved analysis capability, improved legibility, and more efficient recordkeeping.

Additional benefits would be accrued by police agencies using portable computers in the field. The use of computers will allow police officers the opportunity to read and store identification information from magnetic stripes on driver's licenses, bar codes, or smart cards if and when a State begins to issue them. Moreover, the computers can be utilized as a Mobile Data Terminal (MDT) within a computer-aided dispatch (CAD) system. These CAD systems, which are growing in number, allow community policing and the two-way exchange of digital data. Portable computers can also be used with improved location technologies such as nondifferential or differential GPS receivers to store location coordinates with the appropriate accident record/report. Lastly, the portable computer may have a role within the context of improved invehicle navigational systems and vehicle tracking systems.

MODEL INTEGRATED ACCIDENT DATA COLLECTION SYSTEMS

In discussing these technologies, it becomes apparent that no single technology can satisfactorily address all problems. However, a combination of technologies could achieve the key objectives of police officers, State agencies responsible for accident records systems sections, and highway safety analysts. For police officers, the model system should make the job of collecting data to prepare an accident report easier and reduce the time it takes for the officer to complete an accident report form. For the State agency, the system should improve the efficiency of the operation and reduce the time and costs associated with creating records for the accident records data base. For the highway safety analyst, the model system should improve the quality, accuracy, and reliability of the accident records data base and improve the timeliness of the data.

Due to the different goals and constraints of State and local police agencies and State agencies, it is difficult to define one ultimate model system that would be appropriate for all States. However, it is possible to identify the key components that could be combined to form a variety of model integrated systems. The key component technologies are described below:

Portable computer. The computer becomes the cornerstone of the system. Without a computer or some type of recording device, it would not be possible to utilize identification technologies on driver's licenses, on registration cards or stickers, or on vehicles. The computer's portability is important since it would allow the officer to record information outside of the vehicle. Desirably, the computer should accept input via pen or keyboard. Moreover, the computer should also function as a mobile data terminal (MDT) within the police department's computer-aided dispatch (CAD) system. The system should have digital linkages to transmit information to and receive information from the police dispatch, local police records section, and the State's driver and vehicle records data base. Additionally, the model integrated system could include the following features:

- A plain paper printer in the vehicle with appropriate cable linkages to the computer.

- The capability to call up and retrieve at the remote accident scene, a detailed and accurate base map from a GIS.

Location Technology. GPS appears to be the most promising in terms of its ability to affect an improvement in the quality of accident location. The model system should functionally allow the automated transmission of the readings obtained from a differential GPS directly to a computer file. For example, the differentially corrected latitude and longitude coordinate data is downloaded directly from an invehicle differential GPS receiver to a notebook computer. Additionally, the model integrated system could include the following features:

- A portable differential GPS receiver that allows the officer to obtain and store a reading at a location outside the police vehicle (e.g., officer parks upstream of accident and then walks to point of first impact to take the reading).

- Automated vehicle location system that allows the police dispatcher to monitor and track police vehicles in real time.

Driver Identification Technology. Substantial benefits would occur if all drivers had driver's licenses encoded with their name, street address, city, state, date of birth, expiration date, etc. and the police officers had devices to capture this data. Moreover, if all States abided by the same standards for this technology, then a police officer in one State could read the data for a driver with a license from a different State. At this point in time, magnetic stripe and magnetic stripe readers are the most appropriate since several States are now issuing driver's licenses with magnetic stripes. In the future, the smart card may emerge as a better alternative. Additionally, the model integrated system could include the following features:

- A portable magnetic stripe reader or an appropriate reader for another identification technology that would allow the officer to read and store the data from the driver's license while outside the police vehicle.

- Automated two-way data link with the State's driver records data base.

Vehicle Identification Technology. In a manner similar to driver data, the model system should include an identification technology encoded with vehicle identification and the police officer should be equipped with devices that can read this data. While the current trend appears to be toward a limited amount of vehicle data encoded as a bar code on the vehicle, identification technology should contain all relevant vehicle data (e.g., license plate number, VIN, make, model, year, etc.). This would obviate the need for subsequent linkages of other data bases to retrieve data for additional elements. In the future, smart cards installed in the vehicle are likely to emerge. Additionally, the model integrated system could include the following features:

- A portable reader for another identification technology that would allow the officer to obtain vehicle data outside the police vehicle.

- Automated two-way data link with the State's driver records data base.

Digital Camera. With appropriate linkages to transmit digital images in real time.

EMERGING TECHNOLOGIES FOR TOMORROW

Although some may require additional development, these emerging technologies have significant potential in terms of improving the accident data collection/reporting process in the future. It is anticipated that significant advances will be made in terms of the capability of optical character recognition (OCR) software to interpret handwritten characters, numbers, and letters. As OCR becomes more advanced, pen-based computers and form reader systems that can extract data from handwritten forms will become more attractive, not only in terms of cost, but also in terms of effectiveness.

Computers with voice input appear to be the most attractive to police officers at the scene of an accident attempting to complete an accident report. Unfortunately, there are too many drawbacks to current systems, such as susceptibility to background noises and some noises being mistakenly recognized as input. The current vocabulary may not be adequate to accommodate the wide range in names, addresses, vehicle descriptions, and a host of other information that must be recorded for an accident. Moreover, voice input systems are very expensive. However, as the level of sophistication of voice input systems continues to develop, they may become an effective alternative in the future.

In addition to their possible use as a driver's license or a vehicle title card, it is possible for "smart" cards to also store driver records, including revoked licenses, outstanding warrants, citations, convictions, accident history, etc. Police officers could then access these records at an accident scene, rather than running a check of a driver's license using voice radio communications with the dispatcher. Moreover, this application might allow police officers to identify problem drivers and get them off the road.

The use of digital cameras can be an efficient means of collecting critical data at the scene of an accident in a timely manner. Many times, clearing the scene of an accident to free traffic is more important than obtaining complete accident information. The use of a digital camera allows the officer to take pictures quickly, as opposed to drawing a sketch of the accident scene. The pictures taken with a digital camera can be downloaded to a computer (using a cable) and analyzed at a later time to determine other accident characteristics. It is also possible that post-processing software could be developed to assist in the analysis of the physical evidence for accident reconstruction. More importantly, images can be transmitted via modem from accident site to other locations, such as accident reconstruction teams. This represents a significant improvement over the use of conventional cameras.

For accident reconstructionists, much of their time in the field is devoted to obtaining detailed measurements and creating an accurate base plan drawing of the scene. The process is tedious and time consuming. The adverse impact to traffic of closing one or more lanes for accident investigations can be very significant. The use of portable surveying equipment to automate the collection of detailed field measurements for accident reconstruction purposes appears to be very promising. One recent evaluation found that using total work stations to conduct an accident investigation of a serious accident required only 46 percent as much time as was required for investigations using tape measurements.[6] It is anticipated that the devices will improve over time with respect to user friendliness (e.g., police officers are not trained surveyors), portability (e.g., a handheld unit would be most advantageous), and cost.

With improved automatic vehicle monitoring and tracking systems, response times to accidents could be reduced. In addition, advanced invehicle navigation systems should enable police officers to locate and travel to accident sites in a shorter time period. This technology has been marketed for the fleet management industry and is not restricted solely to police vehicles or emergency vehicles. While it was beyond the scope of this research project, improved accident detection can further improve accident data collection in the future by reducing response and clearance times. The appropriate personnel and equipment can be dispatched much sooner to the accident site, thereby decreasing the traffic disruption costs and delays to the motoring public.

Invehicle black box technology has significant potential for enhancing vehicle safety by providing accurate and complete information regarding driver or vehicle actions prior to and during an accident. There are no known applications of driver/vehicle performance recording devices (e.g., "black boxes" similar to aircraft flight recorders) self-contained within private vehicles to date. However, it is feasible to develop monitoring and recording devices that can collect data regarding the status of critical vehicle components, vehicle speed, vehicle direction, turning movements, weather conditions, driver condition, and driver actions. Many automobiles already have monitoring systems for critical components that can be connected to a black box. However, a barrier for use in automobiles is the cost to consumers who must perceive a personal benefit before they are willing to pay for additional devices. Reduced insurance costs might provide an incentive. If black box devices can be produced inexpensively, they might be mandated for use by legislation.

The application of heads-up display technology to accident data collection is limited. For most cases, the major benefit of the heads-up display is to allow police officers to obtain and read information while driving. In contrast, most accident data collection takes place while the police cruiser is parked. However, there may be potential future applications as the technology becomes fully developed.

REFERENCES

1. Highway Traffic Safety Act of 1970, Standard No. 9, "Identification and Surveillance of Accident Locations."

2. Highway Traffic Safety Act of 1970, Standard No. 18, "Accident Investigation and Reporting."

3. F. M. Council, et al., Accident Research Manual, Report No. FHWA/RD-80/016, U.S. Department of Transportation, Federal Highway Administration, Washington, DC, February 1980.

4. J. S. Ludwick, Jr., "Comparison of Three Loran Position-Determination Techniques in the Los Angeles Area," Transportation Research Record 770, Transportation Research Board, National Academy of Sciences, Washington, DC, 1980, pp. 29-34.

5. P. Davies, et al., Assessment of Advance Technologies for Relieving Urban Traffic Congestion, NCHRP Report 340, Transportation Research Board, Washington, DC, December 1991.

6. "Dallas Transit Agency To Use GPS Vehicle Tracking System," The Urban Transportation Monitor, August 30, 1991.

7. L. N. Jacobson, B. Legg, and A. J. O'Brien, "Incident Management Using Total Stations for Collision Investigation," A paper presented at the 71st Annual Meeting of the Transportation Research Board, Washington, DC, January 1992.