Highway Safety Data: Costs, Quality, and Strategies for Improvement, Final Report

PUBLICATION NO. FHWA-RD-96-192

JANUARY 1998

U.S. Department of Transportation
Federal Highway Administration

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

FOREWORD

This study was conducted by the Northwestern University Traffic Institute, Evanston, IL, under Federal Highway Administration (FHWA) contract no. DTFH61-91-C-00051.

This report provides details on data collection methodologies and how to package them effectively to meet the needs of individual agencies. Two related reports, completed under the same contract, are also available. One, entitled *Safety Data: Costs, Quality, and Strategies for Improvement, Executive Summary* (FHWA-RD-96-027), provides a summary of the costs and quality of highway safety data and the strategies to improve the data. The other, *Safety Data: Costs, Quality, and Strategies for Improvement, Research Report*, (FHWA-RD-96-191), identifies, in detail, the issues and costs related to collecting and managing highway safety data and proposes ways to resolve them.

Copies of these reports will be available from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161. A limited number of copies will be available from the R&T Report Center, HRD-11, FHWA, 9701 Philadelphia Court, Unit Q, Lanham, MD 20706, telephone: (301) 577-0818.

A. George Ostensen
Director
Office of Safety and Traffic
Operations Research and
Development

NOTICE

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA-RD-96-192		

4. Title and Subtitle HIGHWAY SAFETY DATA: COSTS, QUALITY, AND STRATEGIES FOR IMPROVEMENT, FINAL REPORT	5. Report Date January 1998 6. Performing Organization Code
7. Author(s) Ronald C. Pfefer, Richard A. Raub, and Roy E. Lucke	8. Performing Organization Report No.
9. Performing Organization Name and Address Northwestern University Traffic Institute 405 Church Street Evanston, Illinois 60208	10. Work Unit No. (TRAIS) 3A3B 11. Contract or Grant No. DTFH61-91-C-00051
12. Sponsoring Agency Name and Address Office of Safety and Traffic Operations R&D Federal Highway Administration 6300 Georgetown Pike McLean, Virginia 22101-2296	13. Type of Report and Period Covered Final Report December 1991 - January 1996 14. Sponsoring Agency Code

15. Supplementary Notes

Contracting Officer's Technical Representative (COTR): Jeff Paniati, HSR-20

16. Abstract

The goal of this project was to analyze the collection and management of highway safety data by identifying issues and costs, and proposing means of resolving those issues and reducing the costs. Initial emphasis addressed known elements of the highway safety system, with an emphasis on collecting and storing relevant data. Sources included the literature and what the States, local agencies, and researchers throughout the Nation were doing to improve data handling for the three largest sources--traffic crash, roadway inventory, and crash injury (emergency medical services and trauma). Visits to various providers of data throughout the United States helped identify and classify issues, along with exemplary practices. A total of 41 issues were listed that affected collecting, storing, and managing traffic crash, roadway inventory, and medical data. The most important issue is that of quality, with data accuracy being the most critical. Lack of coverage is becoming an increasing problem that affects information used to recommend countermeasures.

A major thrust of the research was directed toward identifying the costs of collecting, reporting, and managing safety data. Lack of cost data or lack of applicability of most data collected for roadway inventory and crash injury preclude an extension of the cost model beyond that of crash reporting. The three processes--collecting, reporting, and managing crash data--are estimated to cost $19.20 per crash report filed, based on personnel and equipment costs, but disregarding "sunk costs." Additionally, the report estimates a range of costs by severity of the crash, number of vehicles involved, and region of the country. These ranges were found to be significantly less than those estimated by others.

Finally, a set of strategies was identified, along with goals to be met. The research team identified 23 strategies that were capable of being introduced without requiring substantial additional effort. A number of strategies were taken from exemplary practices discovered at the State and local levels. Each of these strategies was evaluated as it related to meeting the goals and objectives, and reducing the costs of operation. The report concludes with a discussion of how strategies may be grouped and introduced as a package. All of the recommended strategies will provide both short- and long-term benefits.

17. Key Words	18. Distribution Statement
Costs, safety data, strategies, crash data, roadway inventory, medical data.	No restrictions. This document is available to the public through the National Technical Information Service, Springfield, VA 22161.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	95	

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

HIGHWAY SAFETY DATA: COSTS, QUALITY AND STRATEGIES FOR IMPROVEMENT
FINAL REPORT

Table of Contents

Table of Contents (continued)

Table of Contents (continued)

List of Figures

List of Figures (continued)

List of Tables

HIGHWAY SAFETY DATA: COSTS, QUALITY AND STRATEGIES FOR IMPROVEMENT FINAL REPORT

1. Purpose and Scope of the Project

Purpose

Passage of the Intermodal Surface Transportation and Efficiency Act (ISTEA) in 1991 resulted in the commission of seven management systems, each containing as a core element an information system. The Safety Management System (SMS) was one of the seven which addressed highway safety. Within the SMS, the highway safety information system provides the intelligence for making cost-effective decisions.

A need exists to also assure that information the system delivers is of sufficient quality for users, and that it is collected and maintained in a cost-effective manner. Information systems should exist to support decision-making, and this requires data of a quality commensurate with the nature of the decisions being made. However, there are limits on how much of the available resources can be allocated to providing quality data.

Scope

This project seeks to provide guidance for dealing with cost and quality issues associated with the collection and management of highway safety data. The key data source for highway crashes is the police crash report (PCR). However, safety data are collected by a variety of organizations and agencies which comprise the range of members of the highway safety community. Many of the agencies perform functions not directed toward highway safety analyses. These occur at four levels within the system; Federal, State, local, and private. The prime sources are:

1. Traffic law enforcement.
2. Engineering.
3. Medical.
4. Motor vehicle administration.
5. Automobile insurance industry.
6. Adjudication.
7. Education.
8. Highway safety agencies.
9. Involved persons.
10. Involved private companies/agencies.

For this project to address all of the sources identified above was beyond time and resources available, so the scope was narrowed to three key ones as shown in table 1. The primary focus selected for the project was the PCR. However, the use of roadway inventory data was also selected to be addressed with emphasis on road attributes. Finally where feasible, medical sources were considered primarily to evaluate them for acquisition of data on injury severity and driver condition prior to the crash.

Table 1
Data Sources Studied

- Crash Report
- Roadway Inventories
- Emergency Medical Care

Four objectives guided the study:

1. Determine the costs currently associated with collecting and managing highway safety data with emphasis on traffic crash reporting.

2. Determine the quality of the data collected for three sources: traffic crashes, roadway inventory, and emergency medical services provided to crash victims.

3. Identify issues which affect the collection, storage, and use of data from the three sources.

4. Recommend strategies for reducing costs, improving quality, and resolving other issues which affect the collection, management, and subsequent use of the data.

Two other key research efforts are contemporary with, and were concluded prior to, this one. An NCHRP synthesis identified the state-of-the-practice for improving quality of crash data.* This was based, in part, upon telephone interviews with selected States. A companion to this project focused upon potential technological aids to crash data collection.** In its conclusions, this study draws upon the results of these two recent efforts both to avoid duplication and to extend the work in a more substantive manner.

* O'Day, James, *Accident Data Quality,* Synthesis of Highway Practice 192, National Cooperative Highway Research Program, Washington, DC 1993.

** Hughes, Warren, E., *New and Emerging Technologies for Improving Accident Data Collection,* FHWA Report Number 92-097, March 1993.

Use of the Report

The report provides the reader with three types of useful information:

1. Documentation of the current processes and costs for collecting and managing safety data in several State and local agencies, so that other agencies can better assess their work and expenditures.

2. Highlighting typical problems faced by a variety of agencies in maintaining the quality of safety data that it provides to users so that it also may help focus the review of processes related to the collection, management, and use of the data, and

3. Providing a list and assessment of useful ideas regarding cost-effective strategies that may be used for improvement, to help generate ideas.

The remainder of the document is organized around those three areas. It begins with a discussion of the process and cost of collecting and managing safety data; it continues by identifying the variety of issues that are related to producing quality data, and it concludes with a listing and detailed discussion of a variety of strategies that may be employed to improve quality and lower the cost of collecting and managing safety data.

2. Project Approach

Initial Work

The study set out to determine what was known related to costs and quality of highway safety data, then to fill key gaps in the knowledge. The intent was to produce a "first cut" at the objectives for the project, especially for identifying applicable issues and testing the feasibility of establishing a model for estimating costs. For this purpose, initial work was based upon:

1. Literature reviews.

2. Responses received from an initial inquiry to the Governor's Highway Safety Representative of each State.

3. Pilot studies conducted in one State.

4. Previous knowledge of the project team.

As a result, the team discovered a large body of knowledge regarding the collection and management of crash data, but limited published material regarding the other two sources (roadway inventory and medical data). The literature describing costs of obtaining and managing data was almost non-existent. The initial work produced:

1. A synthesis of the literature.

2. A plan for field data collection.

3. A framework for analyses.

4. Preliminary models for estimating the cost of collection and management of crash data.

Data Collection

Selection of sites to visit. An integral part of the project was visiting traffic safety agencies in several States to document processes and issues related to safety data collection and management. Sites were selected to address a range of practices and conditions related to the handling of safety data, and to examine those States with exemplary practices.

From a matrix of attributes about each State decisions were made as to what sites should be visited. Data about attributes were obtained through telephone interviews of safety data base managers or State traffic engineers. Supplementing the interviews was information gathered from a number of sources including personal contacts. The States also were organized by region - northeast, south, north central, and west.

A set of primary sites was selected (shown in bold in table 2). The research team performed a comprehensive set of activities at each site, including:

Table 2
List of States Selected for Visits

New Jersey	**Michigan**
Pennsylvania	**Wisconsin**
Virginia	Illinois
Florida	Utah
Ohio	**California**

Bold items are primary sites

1. Direct measurement of police officer's time to complete the PCR.

2. Documentation of data-management costs and procedures related to handling the PCR.

3. Documentation of collection and management procedures for roadway inventory data.

4. Documentation of collection and management procedures for emergency medical services and trauma injury data.

5. Conduct of focus groups with users of highway safety data, regarding uses of the data.

6. Documentation of noteworthy practices.

7. Acquisition of selected crash reports and crash files for further assessment.

The results of the visits are summarized in several reports. The most comprehensive set of data appear in reports about the sites, including a review of safety data management, roadway inventory, costs, and exemplary practices. These are contained the *State Data Book**, an unpublished project document.

PCR completion-time. There were very limited data available in the literature regarding the time that a police officer or other type of data collector spent at traffic crash scene, and how much of that time was spent collecting safety data. The project team devised a simple form to measure the components and total time spent by an officer collecting data and performing other duties at the site of a crash. Direct measurement of PCR completion-times prove to have low productivity; therefore, the team devised a self-reporting instrument for officers to complete for the project. While this had less validity than direct measurement, the potential sample sizes and cost-effectiveness was considered superior.

* A copy of the *State Data Book* is available from the Transportation Library at Northwestern University, Evanston, Illinois.

Data management costs and procedures. Similar procedures were used to document data collection and management procedures for PCR's, roadway inventories, and medical sources. In each case principal managers of the data at the State level were interviewed regarding the process. Representatives from local agencies which represented data collectors also were interviewed. Furthermore in the case of PCR management, the interviewees were asked to provide as detailed a set of information, as feasible regarding the costs associated with the operation. In many cases, more than one State agency was involved in the management of PCR data. An attempt was made to interview representatives from each agency. Most agencies provided manuals, diagrams, and other materials which documented the procedures in more detail than could be derived from the interview.

Conduct of focus groups with users. During visits to primary State sites, the project team held a focus group session with users of highway safety data. The groups averaged about five users; some had twice the average. Although the selection of users was left to the ultimate judgement and willingness of the local host, the groups generally were well rounded with local and State users representing a variety of disciplines, and even participation of representatives of a few private groups. Each individual in the group was first asked to describe their agency's functions and what safety analyses they performed. The group leader (one of the project team-members) then selected several of the examples and requested that the individual describe the analysis in detail, providing sample results where possible. The group was then asked to comment on the quality of the data using a set of definitions for quality that were provided by the group leader. Finally, the group was asked to describe any analyses they were unable to do because of lack of data or lack of accessibility to the data.

Documentation of noteworthy practices. As the team members identified some practice being used that was considered unique or exemplary during the course of interviews and focus-group sessions, they would pursue its documentation. A general framework was developed for the interviewer to follow, but the interviewees were given complete latitude to describe the practice in a manner they saw fit.

Acquisition of selected crash reports. A request also was made of the primary manager of PCR data to provide between 25 and 50 crash reports as they existed prior to any handling. The request also included a copy of the printed records created from the selected set of crash reports. The selection of the set of crash reports was left to the agency, to avoid creating undue burden by imposing a randomized process. Subsequent review of the reports suggested that selection came from those PCR's immediately available, and this probably was random. The agency knew, however, that the purpose of the request was so that the project team could analyze the quality of the original PCR and the degree to which the management process improved the quality.

Definition of users and uses. A detailed definition of users and uses of highway safety data was developed based upon the results of the efforts described above. This included a taxonomy of users and the types of data that are desired. The data needs of each user were described. In addition, scenarios were developed to typify the range of uses being made of highway safety data.

Analyses

Aspects of the analyses. A series of analyses were performed on the data collected during the site visits as well as that acquired from other sources. The collected data and resultant analyses were used to develop estimates of the cost of collecting and managing highway safety data and to assess the quality of these data. Steps in the analyses included:

1. Tabulation and development of descriptive statistics for PCR completion times.

2. Derivation of total and unit costs for PCR data management.

3. Assessment of crash report data quality by analyzing copies of PCR's as submitted by law enforcement agencies and comparing them with the final data base record created from each PCR.

4. Derivation of estimates of national frequencies of highway crashes, by type, using the General Estimates System (GES) maintained by NHTSA.

5. Derivation of estimates of average salary rates for law enforcement personnel using a data base available through the Law Enforcement Management and Administration Statistics (LEMAS) data base maintained by the Bureau of Justice Statistics of the U.S. Department of Justice.

Design of strategies. The remainder of the project focused upon extracting from the variety of information a list of issues to be resolved related to the quality and cost of collecting and managing highway safety data. An additional focus was identifying and assessing alternative strategies for resolving the issues and recommendations for further research and demonstration.

Figure 1 on the following page depicts the process that was followed in establishing the strategies. Goals, objectives and measures of effectiveness were derived as a means for defining the desired State of safety data collection and management. This provided a basis for developing a set of principles that should be followed when developing strategies for improving collection and management of the data. It also provided the reference base for assessing the current status of safety data collection and management systems.

The assessment involved comparison of objectives with current status so that where the system did not meet objectives an issue needing resolution could be articulated. Each of the issues was considered and a set of strategies defined which sought to meet the identified objectives.

Development of strategies was aided by reference to current noteworthy practices that had been identified during the field work.

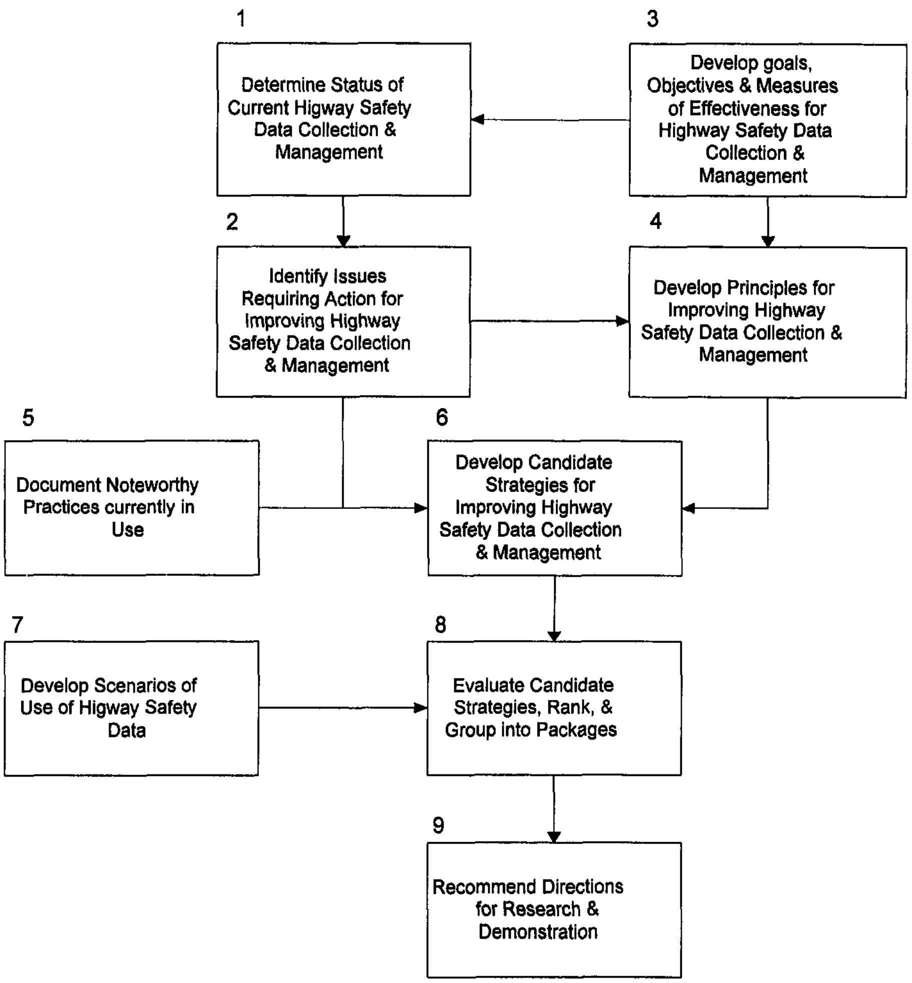


Figure 1
Method for Identifying and Evaluating Strategies to Improve the Collection and Management of Highway Safety Data

In the final steps, the candidate strategies were evaluated and ranked according to their predicted cost-effectiveness. This was done considering a set of scenarios for using highway safety data to relate to the range of users and uses that the system must serve. Assessments were made using a combination of results from an extensive rating of alternatives, and output from the cost model developed earlier in the project. Recommendations were prepared reflecting the findings.

3. Data Collection and Management Processes

Analysis of safety data and collection must begin by establishing an understanding of the process that is used. This allows the system to be disaggregated and studied as elements which can ultimately be re-aggregated. This chapter provides a generic description of the process derived from considering current practices in several States and other agencies.

Traffic Crashes

Figure 2 provides a simplified diagram of crash data collection and management. The diagram shows the process divided into groups of activities related to collecting and reporting, and those related to data management. Aspects that are not directly involved with data collection and management are shown separately. However, these aspects may affect quality and costs. The diagram highlights some key attributes of the process which are discussed further in the next section of the report. They are:

1. Data collection may be done both at and away from the scene of the crash.

2. Data may be entered into the form off-scene.

3. Usually a supervisory review of the crash report occurs at the agency where the data collector works.

4. Often the State safety manager, other agencies, and local levels of law enforcement enter and process the data duplicating the efforts.

5. Pre-processing of the report may occur before it is coded and entered.

6. Location coding often is done as a separate activity often by a separate unit.

7. The PCR is often transferred among several stations during its handling.

Roadway Inventory

Figure 3 provides a schematic of collecting and managing data for roadway inventories. It highlights the possibility that data are received from several sources, including the roadway video log. The State department of transportation (DOT) represents the primary repository of the data. Some observations about this process include:

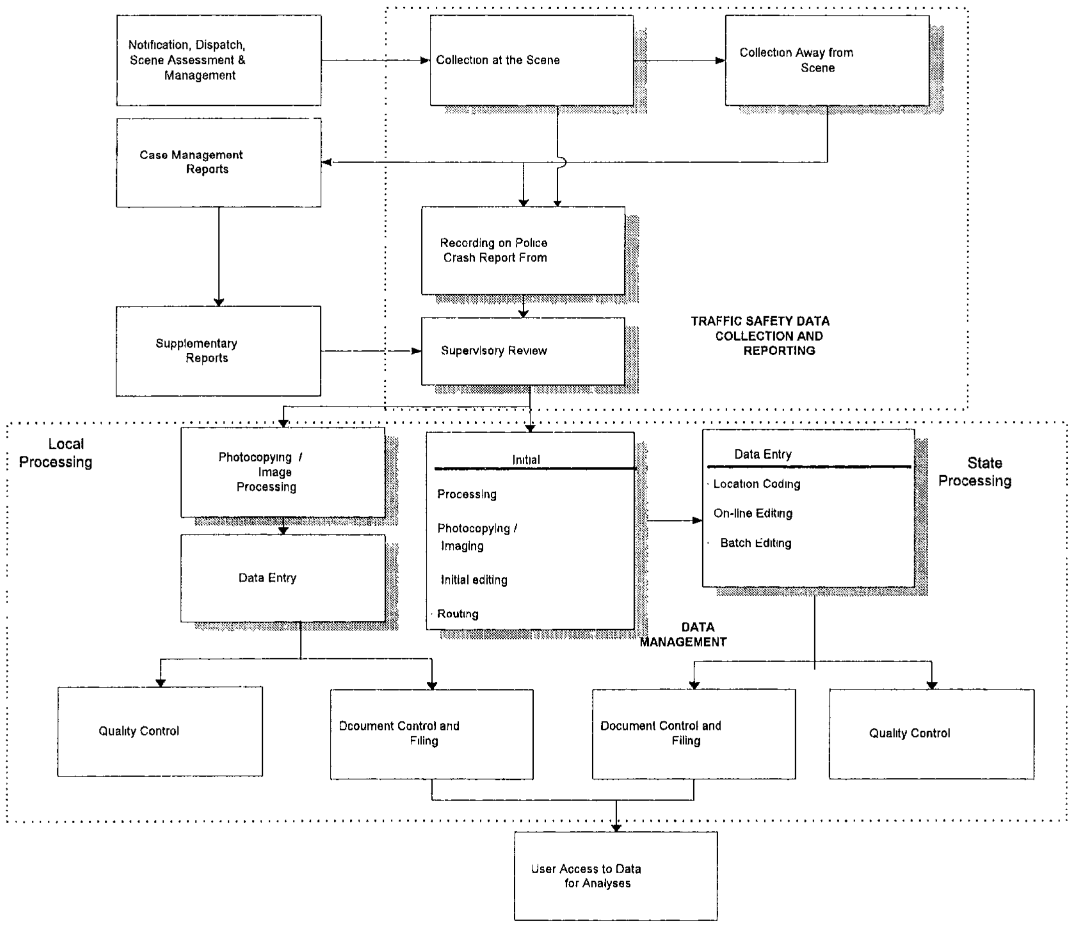


Figure 2
Overview - Process of Data Collection and Management for Vehicle Crashes

1. Roadway inventories may depend substantially upon district personnel of the State DOT to collect and maintain.

2. Updates of the data base may be on a 3- to 5-year cycle with reliance on construction project data sources for interim currency.

3. Attention to data entry and editing often is minimal and quality control practices rarely employed.

4. History files are minimal if they are maintain which is rare.

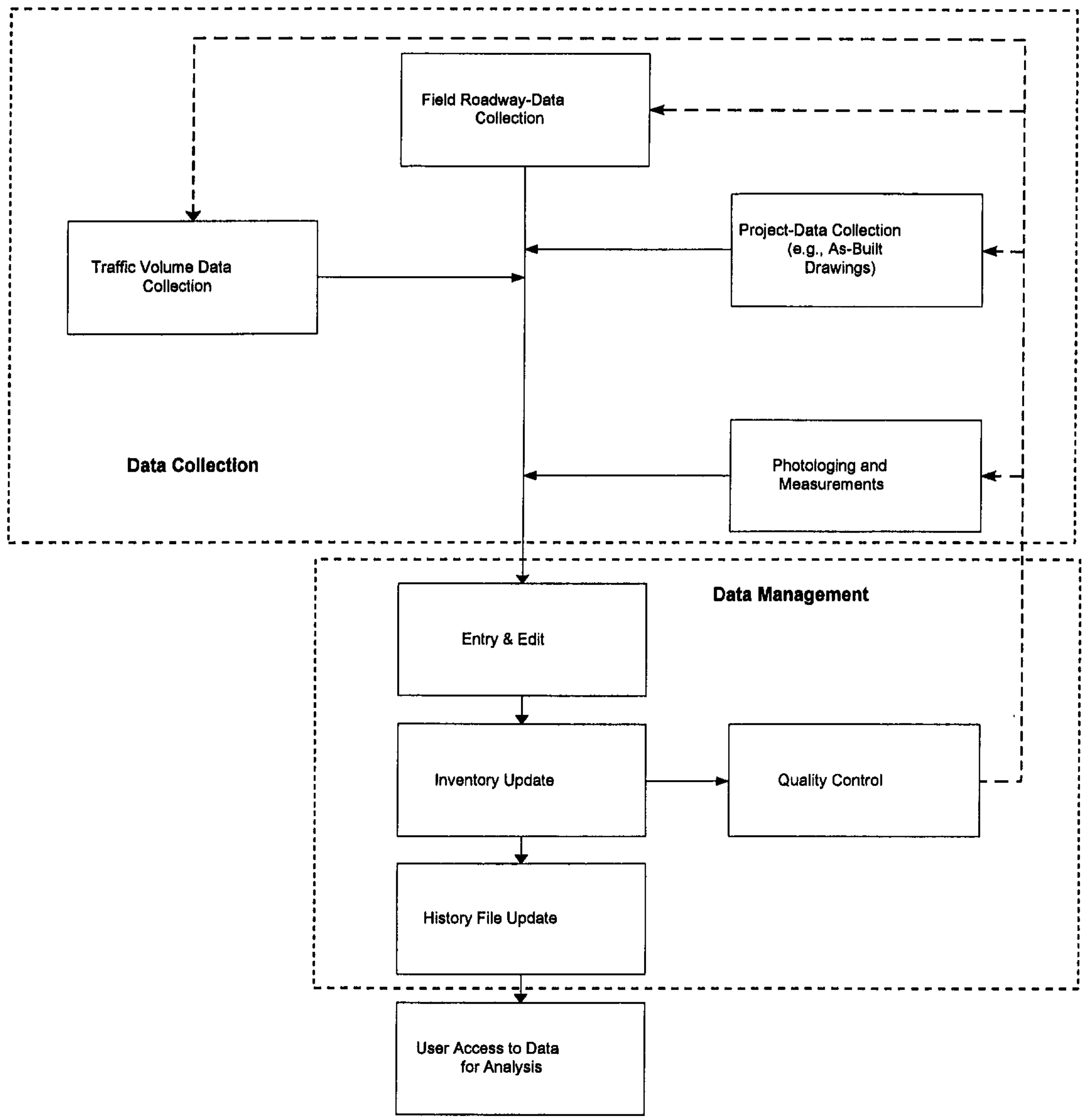


Figure 3
Overview of Process of Data Collection and Management for Roadway Inventories

Figure 4 depicts processes involved with collecting and managing medical data. Observations, especially with regard to the elements of interest to this project (driver conditions prior to crash and injury severity), include:

1. At-scene recording of data is minimal due to focus on patient needs.

2. Data are collected by persons specifically and extensively trained to collect it and the report usually completed at the treatment center after delivery of the patient.

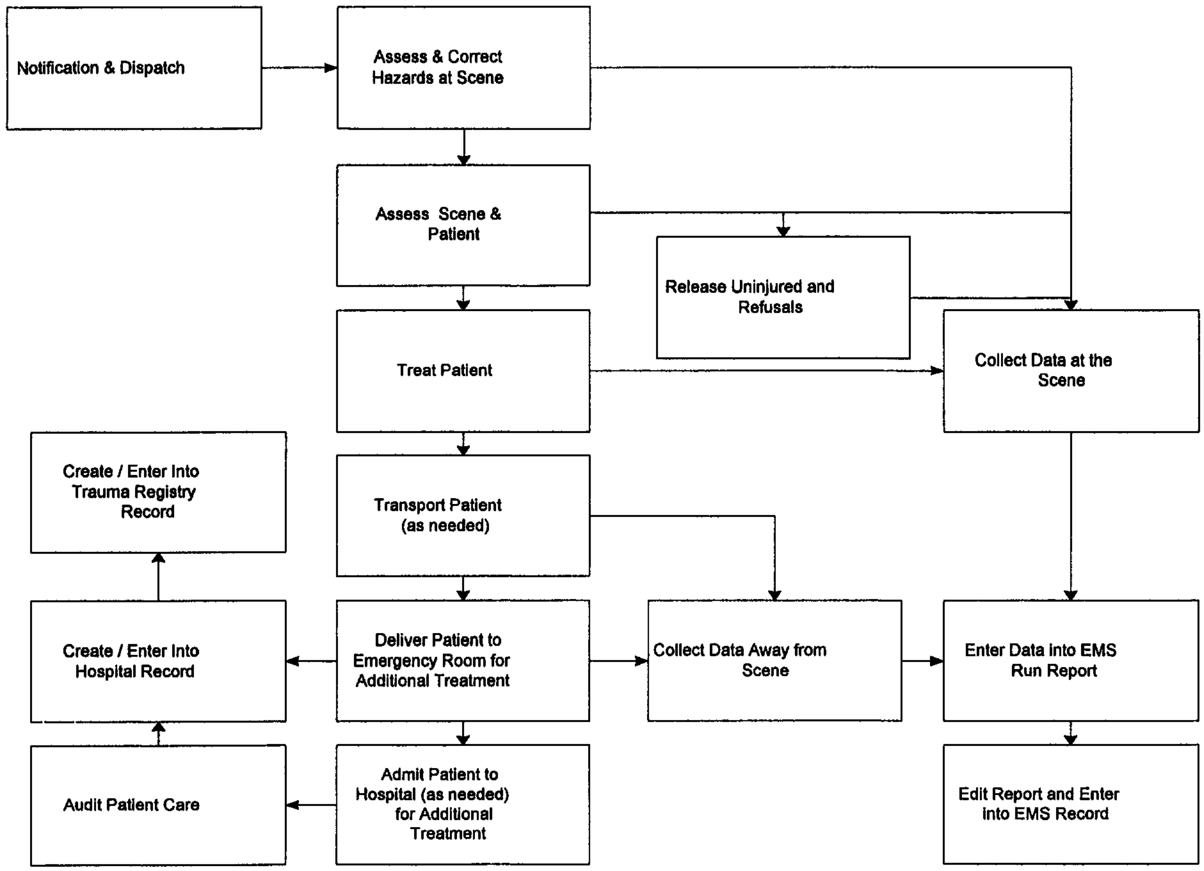


Figure 4
Overview of the Data Collection and Management Process for Medical Sources

3. Data to create a hard link with the crash report generally are not collected.

4. EMS, trauma center and hospital data collection and management are often done independently by service providers.

5. Data systems generally include quality control procedures.

The next chapter discusses the costs associated with data collection and management. Most of the analyses are restricted to crash data because information has been collected and was available.

4. The Cost of Collecting and Managing Safety Data

Objectives for Cost Estimation

In the today's environment of declining resources for public service, the cost of service is a major issue, as is the competition among services for financial support. Within the law enforcement community, the decline of resources is being experienced along with an increasing public sensitivity to crime. This has resulted in a relative reduction in emphasis on the role of law enforcement in traffic safety, including the collection of data regarding crashes.

Knowledge regarding the cost of safety data collection and management is useful for evaluating its cost-effectiveness and for establishing policy on sharing costs. Assessment of cost-effectiveness can be used to establish policies, review alternative strategies and evaluate programs for improved safety data collection and management. Specific objectives of this effort include:

1. Estimating the unit cost of collecting and managing safety data associated with a crash.

2. Estimating national costs associated with safety data collection and management.

Assumptions and Methods

Assumptions. Two basic questions apply when determining whether a cost should be allocated to safety data collection and management:

1. Is the cost associated with safety data. (given a "yes" answer to the first question).

2. If safety data collection were not being done, would the activity occur anyway?

A "no" answer to the first question means that the associated activity is not related to safety data. A "yes" answer to the second question indicates that the costs associated with the activity are "sunk costs" and therefore not applicable. Otherwise, the costs associated with the activity must be allocated to safety data collection.

Instead of a strict accounting of costs allocated over multiple operations in an organization, an alternative approach was used. It estimates the personnel time involved in the collection and management of safety data and calculates costs using salary, employee benefit and indirect cost rates. While this avoids a costly accounting study, it can introduce errors because the indirect-cost rate can include agency expenditures not all applicable to safety data, but which are not feasible to separate, e.g. the cost of a crime laboratory. A rate was derived which excludes, to the extent possible, these potential inaccuracies.

The cost estimation approach being taken for this study also has implications for how to treat costs associated with highway safety data sources. Using the rule of sunk costs established above, the costs of collecting and managing a set of data are not included unless those data were collected specifically for highway safety analyses. Although the data may be usable for highway safety analyses, if it is being collected and managed primarily for other purposes, the costs associated therewith its collection and management should not be accounted to safety data collection and management. Only costs associated with its acquisition for safety analyses (e.g., transfer of data to a safety data base) are applicable.

Applicable cost studies and from literature. The highway safety literature has little to offer on the subject of estimating the cost of safety data collection and management. Initial contact with individual States regarding cost experience was also not productive. One State conducted an analysis of costs associated with processing crash data.* The report contained a significant discussion regarding the duplication in the handling of accident reports. Six different groups within the State manage the reports often duplicating the processes of each other. Costs were estimated for each of these units of government. The results indicated a total unit cost of $7.72 per PCR for data management.

Miller, *et al.*** includes estimates of the cost of police response to traffic crashes and compares them with an earlier NHTSA estimate.*** The values ranged from about $9.00 for a PDO to $185 for a fatal crash. The values derived by Miller were based upon at-scene time estimates provided from a survey of five urban police departments and five State police agencies, each having an automated dispatch operation. The estimates are based upon total reported time the officers logged on the crash. The purpose of their estimate did not lead them to further disaggregation or refinements.

Because the police officer is the primary safety data collector, national estimates are feasible using police salary data available from The Law Enforcement Management and Administration (LEMAS) statistical data base. These data are collected in a national survey of a representative sample of law enforcement agencies, providing data from State and local police departments including general purpose police departments (municipal and county) and sheriff's departments.

---

* Kelsh, *et al.*, *Cost Analysis of Virginia System for Processing Accident Data.* Virginia Highway & Transportation Research Council. Charlottesville, VA: 1984

** Miller, Ted, *et al. The Cost of Highway Crashes.* The Urban Institute. Federal Highway Administration, NTIS. Washington, DC: October 1991

*** National Highway Traffic Safety Administration. *The Economic cost to Society of Motor Vehicle Accidents.* Washington, DC: 1983

Analysis units. PCR's were classified into "analysis units" for cost estimation as shown in table 3. There are six basic cases represented plus variations on each that result from regional factors and area type. The cost of collecting the data was derived taking each of these variables into consideration. Variables shown were considered the most important ones with respect to variation in cost. The choice of categories for each of the variables was somewhat arbitrary to keep the size of the effort feasible. However, the divisions generally follow those used by safety analysts. In particular, the definition of regions was dictated to a great extent by the nature of the available data on costs and crashes.

Table 3
Units of Analysis for Cost Estimation

Variable	Categories
Number of Traffic Units Involved	Single-Vehicle Multiple Vehicle
Severity of the Crash	Property Damage Only Minor and Moderate Severe and Fatal
Region of the United States	Northeast North Central South West
Type of Area	Rural Urban and Suburban

The cost of managing the data was calculated in a more aggregate manner because there is much less variation due to the factors represented in the taxonomy of analysis units. Furthermore, the nature of the available cost data for PCR management limits flexibility for analysis.

Cost Model

Cost of data collection. Figure 5 presents the formulas applied to calculating the costs of collecting and reporting crash data for any analysis unit using the PCR. Although the model allows for four types of personnel, the limitations of classifications available from the LEMAS data-set only allow estimates to be made of salaries for a Sergeant and a Patrol Officer. Specially-trained crash (accident) investigation (AI) specialists may complete PCR's, but often are used only for supporting investigation. Where such units exist, the model uses Patrol Officer salary to accommodate their salary. It is likewise used for the supporting officer.

Because the equations are applicable to any analysis unit, it is possible to use them for estimating costs associated with portions of the PCR, as well as the entire form. All that is needed in such a case are the time estimates for the selected portion of the PCR, for the each type of personnel involved.

Cost of data management. The approach to data management cost estimation is somewhat different than used for data collection. As described in the previous section, the cost model for data collection starts with a disaggregate estimate of the time required to collect data for a given analysis unit, and uses it to compute the portion of an annual salary that is allocable to data collection. The estimate for data management, however, starts with the total annual duty time for the involved staff and uses an estimate of the percent of the person's annual time which is allocable to safety data management to arrive at an annual time allocable to the process.

The different approach taken to estimate management costs reflects the most feasible format for measuring safety data involvement for each type of activity. Managers of these activities can make reasonably accurate estimates of the proportion of staff time involved with safety data. Once unit estimates have been arrived at for data management costs, they can be applied in a reverse mode. That is, unit costs for a new strategy can be estimated using those derived from field data. They may then be aggregated by multiplying by the number of PCR's affected. Figure 6 displays the cost formulas used.

In addition to personnel costs, there are often significant computer system development and maintenance costs. The costs to be included should involve both hardware and software development and maintenance. In general, the nature of safety data systems are such that the computer hardware on which they are housed are used for many other applications. Therefore, the proportion of system use allocable to safety data management is usually so small that it is negligible, unless the agency operating the computer system has a charge-back system. In the latter case, the hardware cost becomes part of the annual operating cost. However, at least one State visited by the project team used dedicated hardware for its PCR management. Equations 6 through 9 were developed for use when hardware and related data processing is dedicated to safety-data management.

While the use of economic factors is strictly required, the precision of the data available for making the estimates of cost and system life is so limited, and the assumptions regarding the interest rates are so arbitrary, that simply dividing the total cost by the life of the system (and assuming a zero salvage value) is considered appropriate as an approximation.

Determination of Values for Independent Variables - Data Collection

Values were determined for each of the independent variables based on information available in the literature and that collected during site visits to selected States. In some cases, the values are considered appropriate and well documented. Some values were arrived at using assumptions or extrapolations. The discussion below provides further details.

Salaries and benefits. Salaries and benefits were determined for police personnel from published data based upon the results of national surveys available in the Law Enforcement and Administration Statistics (LEMAS) data base.

Indirect rates. The LEMAS data-set does not report indirect costs for agencies. Overhead or indirect costs would be preferably estimated directly from a model which accounts for all elements of this type of burden. In one study, Kelsh, Heitzler, and Rauth (1986) arbitrarily decided to use an indirect cost factor of 10 percent of salaries, but this was for data processing.

Based on estimates on the various components of overhead, e.g. equipment, administration, and housing, the project team estimated indirect costs at 90 percent of direct costs.

Annual duty time. Because benefit rates include benefit time off, the full duty year is estimated for the calculations in the cost formulas. The LEMAS-based reference (Hoetner 1990) indicates a consistent use of the 40-h week for law enforcement agencies. This translates into 2,080 h or 124,800 min per year. However, actual on-duty hours average 1760 per year; therefore, the costs must be adjusted by 18.2 percent to represent actual time available.

Cost per Unit

$$C_u^c = \Sigma(S_i/DT_i)*I_{P,i}*T_i^{c}*(1+f_{B,i}+f_{O,i}) \quad (1)$$

for I = PO, AI, SO, and SU

where:

C = cost
u = unit
c = safety data collection
S = annual salary (dollars per year);
DT = annual duty time (minutes per year);
I_P = percent of analysis units involved in;
T = time spent on data collection (minutes);
f_B = fringe benefit rate (pct of salary/100);
f_O = indirect cost rate (pct of salary/100);
PO = Patrol Officer;
AI = Accident Investigation Specialist;
SO = Support Officer;
SU = Supervisor.

and for S, where:

$$S_i = [S_{i/r}\,(1+g)^{(yr - ye)}]*f_R \quad (2)$$

where:

$S_{i/r}$ = salary from reference data;
g = inflation (growth) rate;
y_r = year of salary reference data;
y_e = year of cost estimates;
f_R = regional salary factor.

Total Costs

$$C_t^c = N*C_{uc} \quad (3)$$

where:

t = total;
N = frequency of use of analysis units;

Figure 5. Costs for Collecting Safety Data

Total PCR Management Personnel Cost

$$C_t^m = \sum(n_i*S_i^m*DT_i^m*p_i)\,(1+f_B+f_O) \quad (4)$$

for I = each clerical and supervisor classification involved

where:

S_i^m = hourly salary;
DT_i^m = annual paid-hours;
m = safety data management;
n = number of persons of classification "I";
p = percent of annual hours of personnel time associated with managing safety data.

Estimating Unit Personnel Cost

$$C_u^m = C_t^m/R \quad (5)$$

where:

R = the number of PCR's managed

and:

$$CS = D + M \quad (6)$$

where:

$$D = (D'*CR)-(V*SF) \quad (7)$$

where:

M = annual maintenance and operating cost
D'= the lump sum development cost
V = salvage value of the system
CR = capital recovery factor = $\{g(1+g)^L\}/\{(1+g)^L - 1\}$ (8)
SF = sinking fund factor= $g/\{(1+g)^L - 1\}$ (9)
L = life of the system development investment (years)

Figure 6. Costs for Data Management

Crash data collection time from the literature. Police officers assigned to investigate traffic accidents spend time on many activities which do not directly involve safety data collection. "Other" activities involve managing the crash scene, taking enforcement actions against crash-involved traffic law violators, or attending other administrative tasks, e.g., explaining motorist report forms to involved parties. Obtaining the actual time spent collecting safety data proved difficult. Past studies did not provide estimates of the times applicable to this project.

Field data collection of times. This section summarizes the work done on this project to obtain time estimates for components. The initial plan for timing crash report completion time involved observing and timing officers as they handled a crash. The components measured during the observations are shown in figure 7.

1. Classification by Severity
   a. severe and fatal (K and A-level injury)
   b. minor and moderate (B- and C-level injury)
   c. property damage only (0)

2. Components of Reporting Time
   a. inspecting damage
   b. investigating the scene
   c. interviewing principals
   d. interviewing witnesses
   e. recording crash facts
   f. recording person data
   g. recording vehicle data
   h. preparing narrative
   i. preparing diagram

3. Time Handling the Crash
   a. travel time
   b. at-scene time
   c. other reporting time

Figure 7
Components of Observations

Opportunities were taken to ride with police officers in the expectation of gathering additional data. Overall, the team observed 31 crashes in four States; 22 involved property damage only (PDO) and 9 involved personal injury. The observations were primarily made for municipal law enforcement agencies. A few observations were accomplished with State police. A strong likelihood exists of the observer having an effect on the officer's performance. No better means was identified, however, for directly collecting this information.

Early in the study, the team realized that few crashes could be directly observed using the method adopted. Crashes did not occur with sufficient frequency to productively use project personnel. In an effort to obtain enough data to address at least some of the range of variables listed above a self-reporting form was prepared and given to cooperating police agencies for their officers to complete. Over a 2-month period, the participating departments completed these forms for 274 crashes.

Self-reported times were subject to even more measurement problems than direct observations. However, it was considered the best available alternative. The project team believed that between the two sources reasonable estimates could be derived.

Given that police officers who report crashes would be doing so even if there were no safety-data analyses being performed, much of the time spent on a crash could be considered a sunk cost. However, the method of collecting data probably would be different if only case management were the issue. While difficult to perform, the time spent collecting data for safety management and reporting safety data was estimated separately. The costs for collecting data, therefore, do not include time spent traveling to or unproductive time at the scene.

The average self-reported values for time were skewed by several high values which were considered unreasonable and therefore likely to be in error. An attempt to use a median value from both self-reported and observed times also was unacceptably high because most of the times came from self-reporting. To provide times for computing costs, a compromise was made. The time to collect and record safety data for PDO crashes was taken from the median value for observed cases. Because few observed times existed for injury crashes, the median value for PDO crash was adjusted for more severe crashes based on differences found in self-reported times among the three levels, PDO, minor injury, and severe injury.

In order to establish times for the analysis units, computation was derived from proportioning the median times within each cell in accordance with the variations among self-reported times. Table 4 displays the result of the computations. Figure 8 shows the results graphically.

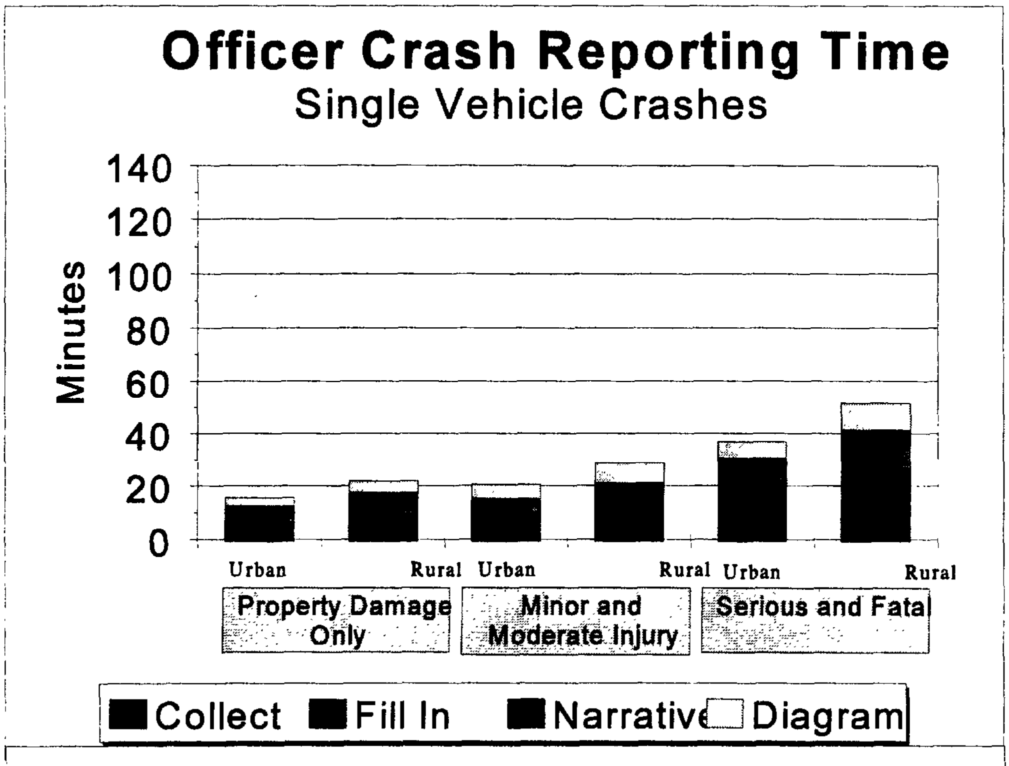
Table 4
Time Spent Reporting Vehicular Crashes
(Combined Self-Reported and Observed Times - in Minutes)

Showing Severity, Location and Number of Vehicles

	P.D.O. (m=22)		MINOR INJURY (m=29)		SEVERE INJURY (m=52)	
	URBAN (m= 22)	RURAL (m= 30)	URBAN (m= 22)	RURAL (m= 30)	URBAN (m= 22)	RURAL (m= 30)
SINGLE (m=17)	12	16	15	21	27	38
MULTIPLE (m= 29)	16	22	21	29	37	52

m = median value in minutes

Involvement of other police in crash investigation. The above time estimates reflect only the time expended by the primary investigating officer on the various cases. In many instances, however, either or both assisting officers or supervisors may appear at the crash scene and



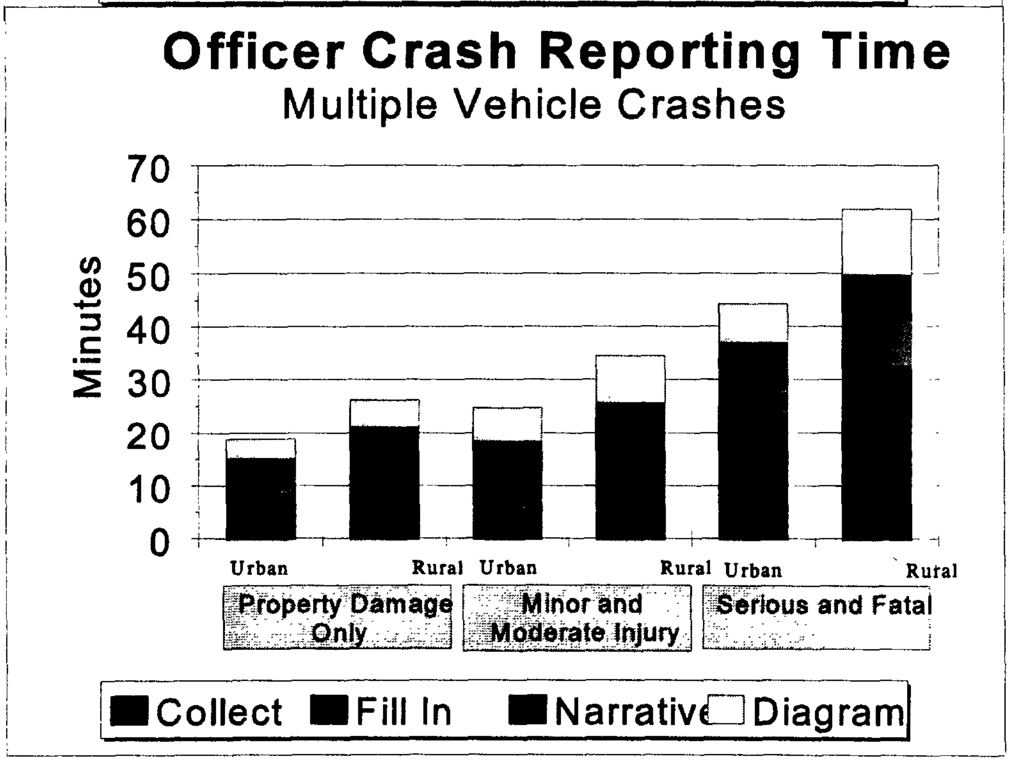


Figure 8
Officer Crash Reporting Time

participate in safety data collection. Also, in many law enforcement agencies, crash investigation specialists will report some of the crashes while others will be reported by general patrol officers. No references were found in any literature that addressed time expended by support officers at crash scenes or the proportion of crashes reported by AI specialists versus patrol generalists. It was not feasible to obtain self-reporting of support officer time, nor were the direct observations representative of the situations normally requiring support personnel.

In most cases, the assistance is needed for non-safety data-related activities such as scene control. However, occasionally support officers also will record names and addresses of passengers and witnesses, and assist with supplementary report forms. The investigating officer still will transcribe the personal information onto the PCR. For crashes where scene measurement is needed, an assisting officer commonly will help with the tape measure or with recording measurements. However, rarely does more than one officer complete the PCR.

As crash severity increases, not only does the likelihood of having support officers increase, but it is also more likely that patrol supervisors will come to the crash scene. While supervisors will less often play an active role in the handling crash process, they can and will fill the same roles as support officers. The amounts of time spent by support officers and supervisors on safety data collection are estimated based on the ride-along, interviews with police officers, and the experience of the project team, but not direct or indirect measurement.

Values shown in table 5 provide estimates of the percent of effort that each of the four groups of officers are expected to give to collecting and recording safety data from any one crash. The amounts were established based upon experience of the project team.

Table 5
Percent of Time Involved for Data Collection at a Crash

PDO = Property Damage Only
M/M PI = Minor and Moderate Personal Injury
SPI & F = Serious Personal Injury and Fatal

No. Traffic Units	Locale	Severity	Percent of Time at Crash		
			Principal Collector		
			Super-visor	AI Specialist & Patrol Officer	Support Officer
Single Vehicle	Rural	PDO	10%	100%	25%
		M/M PI	25%	100%	50%
		SPI & F	25%	100%	50%
	Urban and Suburban	PDO	10%	100%	25%
		M/M PI	25%	100%	50%
		SPI & F	25%	100%	50%
Multiple Vehicle	Rural	PDO	10%	100%	25%
		M/M PI	25%	100%	50%
		SPI & F	25%	100%	50%
	Urban and Suburban	PDO	10%	100%	25%
		M/M PI	25%	100%	50%
		SPI & F	25%	100%	50%

Amount of time by group of officers. Using the median times established in table 4, a set of times can be estimated for each group of officers within the classifications of analysis units as shown in table 6. These are times that each of the groups would be expected to spend collecting safety data dependent on the number of vehicles involved, geographic location, and level of severity.

Table 6
Estimates of Crash Data Collection Time
(for Calculations)

PDO = Property Damage Only
M/M PI = Minor and Moderate Personal Injury
SPI & F = Serious Personal Injury and Fatal

No. Traffic Units	Locale	Severity	Time of Involved Personnel (Minutes) — Principal Collector: Supervisor	AI Specialist & Patrol Officer	Support Officer
Single Vehicle	Rural	PDO	2	22	5
		M/M PI	7	29	14
		SPI & F	13	52	26
	Urban and Suburban	PDO	2	16	4
		M/M PI	5	21	10
		SPI & F	9	37	18
Multiple Vehicle	Rural	PDO	3	26	7
		M/M PI	9	35	17
		SPI & F	15	62	31
	Urban and Suburban	PDO	2	19	5
		M/M PI	6	25	12
		SPI & F	11	44	22

Unit cost estimates. Multiplying the results shown in tables 5 and 6 by unit costs for officers, provides the basis for estimating the costs of safety data collection. The totals for each analysis unit are given in table 7. They range from about $7.00 per PCR for a PDO in a urban/suburban area to $40.00 per PCR for a multiple-vehicle serious injury/fatality crash in an rural area.

Table 7
Unit Costs Adjusted for Proportion of Cases Handled
(Dollars per PCR)

No. Traffic Units	Region	Property Damage Only		Minor & Moderate		Severe & Fatal	
		Rural	Urban & Suburban	Rural	Urban & Suburban	Rural	Urban & Suburban
Single Vehicle	Northeast	10.26	7.41	14.69	12.00	33.29	25.90
	Midwest	10.26	7.39	14.57	11.78	32.47	25.15
	South	8.10	5.84	11.55	9.38	25.95	20.15
	West	10.39	7.49	14.83	12.05	33.34	25.90
	All	9.27	6.68	13.23	10.77	29.82	23.17
Multiple Vehicle	Northeast	12.32	8.89	17.63	14.40	39.94	31.08
	Midwest	12.31	8.87	17.49	14.14	38.96	30.19
	South	9.71	7.01	13.86	11.26	31.14	24.18
	West	12.47	8.99	17.79	14.46	40.01	31.08
	All	11.12	8.02	15.88	12.93	35.78	27.80

Includes involvement of support officers, supervisors, and allocation to AI Specialists
Based upon 1989 salary and benefit values from LEMAS data base

Determination of Values for Independent Variables - Data Management

Methodology. One of the principal activities during visits by project team members to the selected States involved documenting the costs associated with managing crash data.

Information about costs was requested from the host agencies. To avoid burdening the personnel providing information, the team accepted what was provided by the host agency validated only as possible during the course of walking through the processing of the PCR.

Early in the process, the project team discovered substantial variation in practice among the States visited. Furthermore, often two and sometimes three agencies were involved in PCR management. For example, location coding was often done within the department of transportation (DOT). The DOT, however, was often not the agency that managed the crash data, and when it was the manager, location coding was done in a different office of the agency. These divisions of operation made taking a single approach to estimating the cost of data management infeasible.

In some cases, data allowed a fairly accurate count of full-time equivalent (FTE) staff by personnel classification associated with each of the major steps in the managing the data. The agencies were able to supply salary rates by classification in some form as well as a factor used to estimate employee benefits as a percentage of salary. In other cases, the agency was able to give us a total budget for the section managing the PCR's but could not give any disaggregate information. Further, employee benefit factors and indirect (overhead) costs were not known, nor could they be found. Where factors were available, they were used; mostly, they were estimated based upon what was learned in the other States.

Because some operations used the same personnel to perform several functions during PCR management, the teams could not disaggregate the costs of the different activities. However, a cost estimate was made for each State using what was available and making assumptions where necessary to complete the analysis.

Results. Figure 9 provides a summary of the estimated costs for PCR management. The estimates are disaggregated to show data management, entry, and edit activity costs separately from location coding, as well as those associated with the development, implementation and maintenance of hardware and software systems.

The volume of PCR's managed ranged from as few as 15,000 to almost 500,000. Some States had recently revised, or even re-written, their computer processing systems while other States were laboring with systems that had remained stagnant for 10 or more years. Each State determined the information that would be captured in the file from their PCR and the types and severity of crashes that would be reported. Each State also decided which crashes would be location coded and how much supporting information from other computer data bases would be accessed and added to the basic PCR data. The variety of functions performed by the States in this study, the range of sophistication of their computer systems, and the variations in PCR volume, make it difficult to compare one State to another. However, several observations and conclusions can be made that pertain to all the States studied.

The most noticeable similarity between the States was the high proportion costs for manual procedures were to total management cost. In one State, 94 percent of the cost of processing PCR data was associated with manual handling of documents, evaluation of PCR data, and entry of data into computer systems. The lowest percent (low 60's) were found in States which had recently upgraded their computer systems and purchased dedicated computer hardware to improve handling of PCR data. The addition of dedicated hardware and development of computer programs raised their computer costs in relation to manual procedure costs.

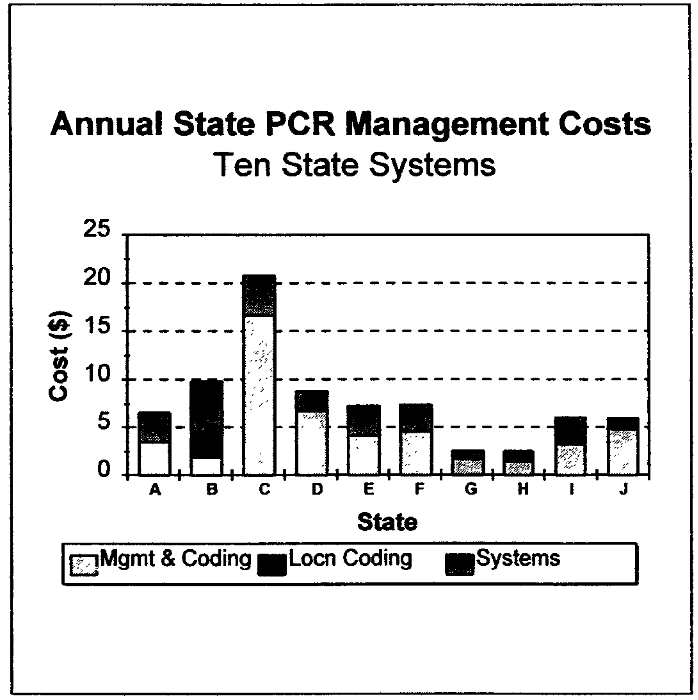
The two States with the lowest cost per PCR (2.44 and 2.42 dollars) had volumes of 350,000 and 400,000 respectively. The gross cost experienced by these two States is similar to States that had far less volume. The high volume in one of these States provided the incentive to automate their PCR processing by developing a scannable form. The other State had a relatively old computerized data base-management system which meant its annual automation costs were low.

Figure 9
Summary of PCR Management Cost Estimates for Study Sites

State	Data Management Entry &Edit	Location Coding	Sub-Total	Hardware/ Software Systems	Total
A (1)	$3.47	$0.07	$3.54	$2.78	$6.32
B (2)	$2.07	$2.31	$4.38	$5.07	$9.45
C (3)	$16.33		$16.33	$3.72	$20.05
D (2)	$6.62		$6.62	$1.83	$8.45
E (2)	$4.20		$4.20	$2.84	$7.04
F (4)	$4.65		$4.65	$2.45	$7.10
G (5)	$1.73		$1.73	$0.71	$2.44
H	$1.50	$0.73	$2.23	$0.18	$2.41
I	$3.35	$1.01	$4.36	$1.46	$5.82
J	$4.80	$0.60	$5.40	$0.36	$5.76
Average	$3.04	$0.94	$5.34	$2.14	$7.48
Standard Deviation	$1.29	$0.84	$4.11	$1.55	$4.96
				Average Without State C:	$6.09

Notes: 1. Does not include FARS operations
2. Where 2 cells are undivided, the estimate is for both operations combined
3. Statistics for data management, entry & Edit, as well as location coding, include only those states where separate components could be determined

Footnotes
1 uses state prison inmates for location coding
2 automated/semi-automated location coding
3 low PCR volume
4 uses state prison inmates for data entry
5 includes development and maintenance of video imaging system



However, it also used a single set of individuals to perform most of the tasks of editing, coding and entry, thus minimizing personnel paper handling. Both other States had developed on-line data-entry and editing programs.

In contrast to these two States, one State which processed almost 500,000 PCR's in 1992 had an annual cost of 5.67 dollars per-PCR processed. This State has not yet chosen to use on-line computer systems for processing PCR data. Instead, it uses a batch entry and editing system with individuals who specialize in just one aspect of the process. In this State, the paper PCR document must be circulated between various specialist groups and agencies, and is monitored by production-control employees to ensure PCR's are not delayed, mis-routed, or lost.

Some States included in this study extract pertinent information from other data bases through computerized linkages. These data, such as driver name and address or roadway features, then can be included automatically with in the PCR record. The linkages can be relatively expensive to develop, but eliminate manual keying efforts when implemented. These linkages may reduce the time required by an officer to complete a PCR in the field by reducing the number of data items that must be captured. However, few data elements are gathered in this manner, and cost savings are therefore not likely to be significant. The major benefit may be in the accuracy of the data gathered in this manner.

Certain conclusions can be made concerning the factors that affect the overall cost of processing PCR data:

1. Economies of scale occur with high-volume PCR processing. A computer system costs essentially the same to develop whether it is used to process 1,000 or 100,000 PCR's. Other economies of scale can come into play. The three States with the highest PCR volume were also the States with the lowest PCR processing costs.

2. Efficiencies can be achieved by minimizing the handling of the PCR, whether it is for coding, data entry, editing, or control. Fewer stations for the PCR improve efficiency of the process. When on-line data entry and edit operations exist, they reduce paper handling. Automated location coding allows entry of the codes directly into a computer file instead of passing the coded sheet back to another section for entry of this one element.

3. Minimizing the data entry tasks will reduce the costs which represent the majority of those currently experienced. Scannable forms are just one example. Use of computers to collect crash data results in electronic fields which can be directly dumped to a computer without keyed entry. The relative efficiency of this latter strategy depends upon how well the computer prevents errors entering the record in the field.

Figure 9 (on the previous page) shows that the average cost for processing a PCR in the States visited is about $7.75 per crash report recorded. This includes data handling, entry, edit, location coding, and hardware and software systems costs. The average is derived from a highly variable set of 10 individual values. State C is significantly higher than the other States, thus having a strong impact on the average. Another example of a source of variation is the frequency with which a system is updated. Those systems that are maintained in a current status will have higher unit costs. The limited sample on which the average costs are based prevents any statistical testing, as demonstrated by the standard deviation of over $5.00. However, it is believed that the sample of States, while not chosen randomly or for representativeness, seems to represent a range of conditions expected across all 50 States.

Estimates of National Frequencies of PCR's

A 1989 file of the NASS-GES was originally used (latest available data at the time the analysis was done) to gain an understanding of the distribution of crashes by severity. The number of crashes are estimated here for the United States as a whole, and for four separate geographical regions as defined in the NASS program. These crashes serve as a basis for estimating the total time spent by police officers in crash investigation. Tables of expected error in these estimates are presented in the National Accident Sampling System, General Estimates System Technical Note, 1988 to 1990. Briefly, the probable error ranges from 11 percent for the smallest estimate to 6.9 percent for the largest, although there are potential bias errors in the these data that are larger than either of these.

Blincoe has shown that GES estimates about 15 percent fewer police-reported crashes overall than counted by the FHWA annual statistics report.* Since the FHWA report comes from data contributed directly from the various States' crash files, it is likely to be more complete. It is not clear which cases are missing in the GES representation. Without more information it is not possible to tell where there are regional variations in missing data. As a result of these uncertainties, the tables have not been adjusted for this factor.

A second kind of missing data is represented by cases that are investigated (taking up police officer time) but are not formally reported (and thus do not appear in FHWA or GES statistics). In the Northeastern Ohio study, Barancik and Fife (1985) reported eight (out of about 500) cases where a police car brought the injured person to the hospital and for which no police report could be located. The effect of this can probably be neglected. On the other hand, work on CODES is indicating cases of hospital admissions (from car crashes) for which no police report could be found.

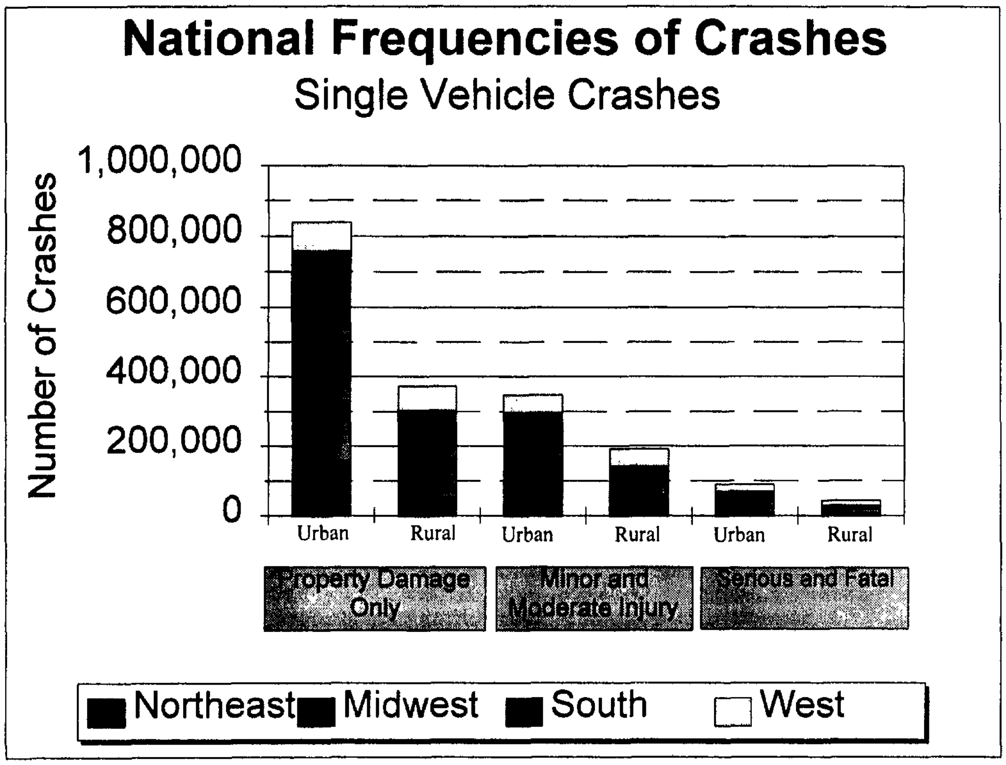
---

* Blincoe, Lawrence J. and Fagin Barbara. *The Economics of Motor Vehicle Crashes, 1990.* National Highway Traffic Safety Administration. Washington, D.C.: September 1992.

As a result of these other considerations estimates taken from the tables presented below are likely to be somewhat understating the actual experience. The impact of these potential variances on costs were measured through sensitivity testing.

There is some concern about injury distributions because States in the southern region exhibit a higher than average proportion of "A" injuries.* The sum of serious and fatal injury crashes (K and A) for the south region (207,932) divided by the sum of all injury crashes for the south region (2,236,960) is 0.0925. For the remainder (the other three regions) of the country the ratio is 0.045, or one-half that of the south. This occurs because the definition used for "A" injury in many of the southern States is considerably more liberal than average. Although some variation exists in other regions, it is not as different as in the southern region. For this study, the severe and fatal injury crashes in the south were adjusted to reflect the percentages elsewhere. This step increased the number of minor and moderate injuries in the south region as compared to what had ben listed in the NASS tables. The revised values are shown in table 8. Figure 10 displays the values graphically for both single- and multiple-vehicle crashes.

* O'Day, James. Private communication with R.A. Raub (Traffic Institute), October 31, 1993.



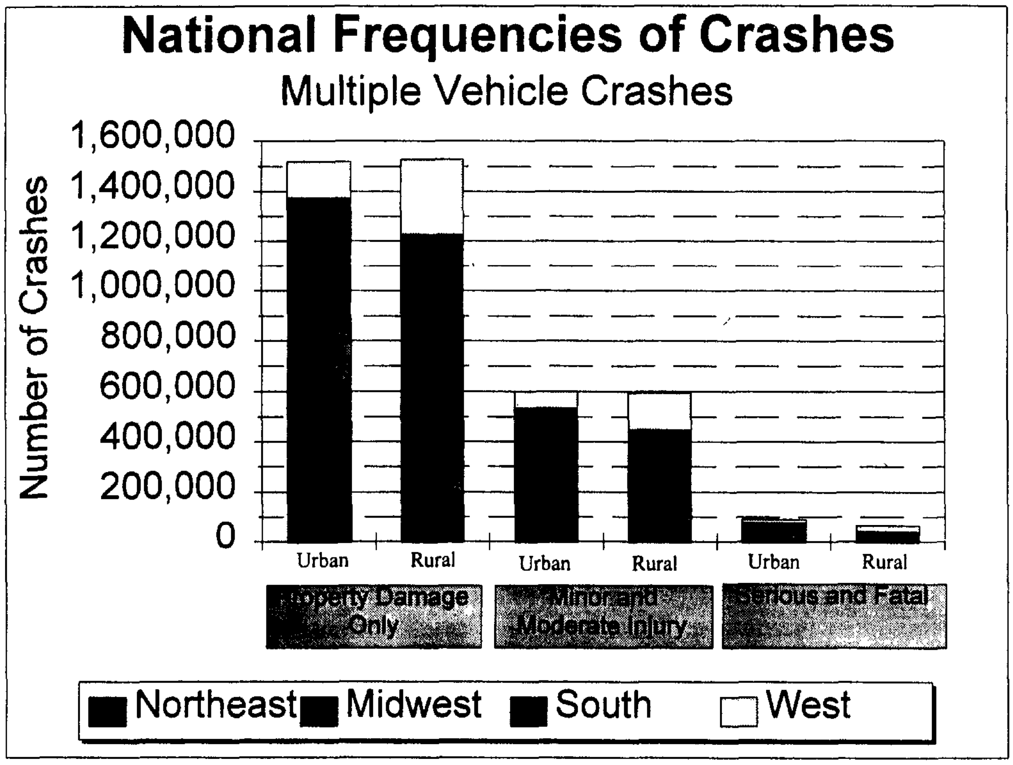


Figure 10
National Frequencies of Crashes

Table 8
1989 National Crash Frequency Estimates Used for Calculations

No. Traffic Units	Region	Property Damage Only		Minor & Moderate		Severe & Fatal		Sub Total		Grand Total
		Rural	Urban & Suburban	Rural	Urban & Suburban	Rural	Urban & Suburban	Rural	Urban & Suburban	
Single	Northeast	162,661	55,042	74,782	45,577	14,648	10,002	252,091	110,621	362,712
	Midwest	381,106	135,738	110,484	41,444	29,256	10,128	520,846	187,310	708,156
	South	225,704	118,951	117,691	59,600	30,536	12,508	373,931	191,059	564,990
	West	81,320	68,227	48,497	47,214	17,470	11,963	147,287	127,404	274,691
	Sub Total	850,791	377,958	351,454	193,835	91,910	44,601	1,294,155	616,394	1,910,549
Multiple	Northeast	278,778	208,339	126,441	90,854	12,137	5,883	417,356	305,076	722,432
	Midwest	574,764	452,877	177,069	128,062	29,515	13,320	781,348	594,259	1,375,607
	South	540,086	586,008	240,764	238,190	38,213	22,709	819,063	846,907	1,665,970
	West	144,427	299,818	64,147	146,099	11,293	20,409	219,867	466,326	686,193
	Sub Total	1,538,055	1,547,042	608,421	603,205	91,158	62,321	2,237,634	2,212,568	4,450,202
Total		2,388,846	1,925,000	959,875	797,040	183,068	106,922	3,531,789	2,828,962	6,360,751

Based upon NASS General Estimates System

Estimates of National Costs of Safety Data Collection and Management

The unit costs described and presented above were applied to the frequencies for each analysis unit, providing estimates of safety data collection and management costs for PCR's associated with each analysis unit. Resulting regional and national estimates of safety-data collection and management costs are shown in table 9 for the values previously derived and presented. This is referred to as the "base condition." The total national cost for safety data collection and management, for the base condition, was estimated at $122 million. Safety data management constitutes approximately 40 percent of the total. The overall unit cost for safety data collection and management associated with a PCR is estimated as $19.20 for the base case. Single-vehicle crashes constitute slightly less than a third of the national cost. National costs generally decline inversely with severity of the crash, primarily in proportion to their relative frequency of occurrence.

The base case discussed above uses 1989 estimates of costs and frequencies of crashes. These were the most recent data available at the time of the original work. While the remainder of the report continues on that basis, the "bottom-line" estimate of unit and total cost was updated to 1994 conditions, using more recent GES estimates, as well as inflation factors applied to underlying costs. The updated estimate resulted in a unit cost of $21.00/crash and a total national cost of about $130 million.

Table 9
Calculated Total National Safety Data Collection and Management Costs

No. Traffic Units	Region	Property Damage Only		Minor & Moderate		Severe & Fatal		Sub Total Rural and Urban		
		Rural	Urban & Suburban	Rural	Urban & Suburban	Rural	Urban & Suburban	Rural	Urban & Suburban	Total Collection
Single	Northeast	$1,670,000	$408,000	$1,099,000	$547,000	$488,000	$259,000	$3,257,000	$1,214,000	$4,471,000
	Midwest	$3,908,000	$1,004,000	$1,610,000	$488,000	$950,000	$255,000	$6,468,000	$1,747,000	$8,215,000
	South	$1,827,000	$695,000	$1,359,000	$559,000	$792,000	$252,000	$3,978,000	$1,506,000	$5,484,000
	West	$753,000	$456,000	$642,000	$509,000	$521,000	$277,000	$1,916,000	$1,242,000	$3,158,000
	All	$7,883,000	$2,526,000	$4,650,000	$2,088,000	$2,740,000	$1,033,000	$15,273,000	$5,647,000	$20,920,000
Multiple	Northeast	$3,434,000	$1,852,000	$2,229,000	$1,308,000	$485,000	$183,000	$6,148,000	$3,343,000	$9,491,000
	Midwest	$7,073,000	$4,018,000	$3,096,000	$1,810,000	$1,150,000	$402,000	$11,319,000	$6,230,000	$17,549,000
	South	$5,247,000	$4,106,000	$3,336,000	$2,682,000	$1,190,000	$549,000	$9,773,000	$7,337,000	$17,110,000
	West	$1,801,000	$2,696,000	$1,141,000	$2,113,000	$452,000	$634,000	$3,394,000	$5,443,000	$8,837,000
	All	$17,101,000	$12,408,000	$9,661,000	$7,797,000	$3,262,000	$1,733,000	$30,024,000	$21,938,000	$51,962,000
Grand Total		$24,984,000	$14,934,000	$14,311,000	$9,885,000	$6,002,000	$2,766,000	$45,297,000	$27,585,000	$72,882,000
								AVERAGE UNIT COSTS		**$11.50**

No. Traffic Units	Region	Crash Data Management Cost					**GRAND TOTAL**
		Data Mgmt. & Entry	Location Coding	Indirect Cost	Hrdwr. & Softwr.	Total Mgmt.	
Single	Northeast	$1,102,000	$342,000	$578,000	$776,000	$2,798,000	**$7,269,000**
	Midwest	$2,151,000	$668,000	$1,128,000	$1,515,000	$5,462,000	**$13,677,000**
	South	$1,716,000	$533,000	$900,000	$1,209,000	$4,358,000	**$9,842,000**
	West	$835,000	$259,000	$438,000	$588,000	$2,120,000	**$5,278,000**
	All	$5,804,000	$1,804,000	$3,043,000	$4,089,000	$14,740,000	**$35,660,000**
Multiple	Northeast	$2,195,000	$682,000	$1,151,000	$1,546,000	$5,574,000	**$15,065,000**
	Midwest	$4,179,000	$1,299,000	$2,191,000	$2,944,000	$10,613,000	**$28,162,000**
	South	$5,061,000	$1,573,000	$2,654,000	$3,565,000	$12,853,000	**$29,963,000**
	West	$2,085,000	$648,000	$1,093,000	$1,468,000	$5,294,000	**$14,131,000**
	All	$13,520,000	$4,201,000	$7,088,000	$9,523,000	$34,332,000	**$86,294,000**
Grand Total		$19,324,000	$6,005,000	$10,132,000	$13,612,000	$49,073,000	**$121,955,000**
				AVERAGE UNIT COSTS		**$7.70**	**$19.20**

5. Quality of Highway Safety Data

The process used to collect and manage data will determine the quality of the data available to potential users. This section presents a definition of data quality used for this project, a taxonomy of users and uses of the data, and identifies major issues associated with maintaining quality during the data collection and management process.

Dimensions of Quality

When the phrase "data quality" is used, it can result in different ideas for different persons. It is not a precise term. It is often used as a synonym for accuracy. Yet, accuracy is only one aspect of quality. Quality was defined fairly precisely for use on this project. It was divided into several aspects which are referred to as a set of dimensions.

1. Accuracy: Degree to which the crash report is correct, both in terms of what is to be included on the report form, and what the collector reports. Veracity is an important part of accuracy. It involves verification of reported facts and care in making observations. Also included is the impact on accuracy of the retention/translation of the report in processing, both in terms of data entry/edit and preserving the edited record in an unadulterated form.

   Accuracy is usually the first aspect of quality that comes to the user's mind. Unless there is confidence that the data are reporting what actually happened, they are useless. A particular problem often expressed to the project team was that police often mis-code the type of collision. For example, when a narrative and diagram are referenced, the crash may be readily identified as a sideswipe although classified as right-angle. Inaccuracies in such items as crash types, location identification, injury severity, pavement condition, light condition, seat-belt use, etc., can either lead to inappropriate conclusions by the user, or (if the user recognizes the shortcomings) inability of some users to use the data for some uses.

2. Precision: Degree of detail and exactness provided.

   Imprecision is often grouped with inaccuracy, but should be considered separately, because different strategies for overcoming them may exist. The KABCO "scale" for classifying injury severity is common on State PCR's. There are difficulties, as discussed above, associated with getting this relatively imprecise scale reported accurately. However, even where it may be reported accurately, it may be too imprecise for some users. Highway design personnel, performing location-specific safety-improvement studies seem to find the KABCO system adequately precise for their needs. However, designers of vehicle interiors find this too crude a measurement system for their purposes. Unless the interior designers have some alternative source of data associated with each crash, they will not be able to perform their function as well as may be required.

3. Completeness: Missing data: Because the collector fails to report them; the report is not submitted to the central repository; the reporting system does not require the data; they are not entered into the system or lost once in the system as a result of error, mishandling, or backlog, or they are not available from the system accessed by the user.

   Missing data will prevent many users from performing the types of analyses that are needed to perform their functions. If data are not being reported that normally should be, there may be a bias created that would render the information useless, unless the nature of the bias were known and adjusted for. If data are not being reported that a user needs, the analyses are just not done. An example is the recognition of the need to report the dynamics of the crash as a sequence of events so that analysts may better dissect crashes to identify underlying factors that contribute to the cause and severity.

4. Coverage: Proportion of the universe sampled and representativeness of the sample.

   The importance of the need for complete coverage of crashes or full knowledge of which are not covered, is not generally recognized among users of the data. Yet it is very critical to the accuracy of their estimates of safety. This is especially true in the context of analyses which involve a period of time (e.g. multiyear studies). If coverage varies over time, and the variation is not random, the conclusions from analyses of the resulting data have the potential for error. Since multiyear data are employed for high-hazard location identification, problem definition, countermeasure evaluation and trend analyses, a significant portion of highway safety analysis is affected by this aspect of data quality.

5. Timeliness: Availability of the data when needed by the user.

   In some cases, it may be possible that highway safety data are accurate, of adequate precision, and properly corrected for the degree of coverage, but still not useful. The reason may be that it becomes available too late for supporting the decision to be made. This may happen because there are lengthy delays getting the report into the database. It may also result when an immediate need for information arises, but the system is not able to provide it within the required time frame. This project focuses upon the former aspect.

6. Consistency: Among observers/collectors and over time, including uniformity.

   Consistency in reporting data is different from, yet similar to, some of the other dimensions of quality cited above. If, within a State, the State police and local police are using different definitions for a data element or reporting threshold, the data cannot properly be combined. It becomes the classical case of combining "apples and oranges." This will make it difficult to perform Statewide or location-specific analyses, where more than one agency reports crashes for an area.

The definition of quality, from these six perspectives, has highlighted how inadequacies can affect the ability of users to make decisions during the course of their activities to manage highway safety. Management involves a series of decisions. For the decisions to be effective, they should be based upon quality information. The quality of information is partly determined by the quality of the data from which it is derived.

It is possible to represent what truly occurred in a manner satisfactory for one set of analyses, but unsatisfactory from another. The specific nature of the analysis, therefore, is an important consideration when defining both the type and format of the data needed along with quality needed for those data. A given data set may be considered high quality to one user according to the dimensions defined above, while of little use to another. Therefore, data must be considered in the context of their use. Many specific uses exist for safety data, each having its unique set of data needs, both in content and the dimensions of quality. While not all of the potential uses can be addressed, the section below provides a further description of activities which occur in performing the various functions in highway safety.

A Framework for Users and Uses

A variety of entities, public and private use or potentially would use highway safety data if they were available in a useful form. Each of these entities has a set of objectives.

To achieve the objectives, the people in the entity serve to perform a set of functions which require them to carry out activities. These activities, in turn, use information to aid decision-making. The information is derived from data available to the agency. The hierarchy is shown in figure 11.

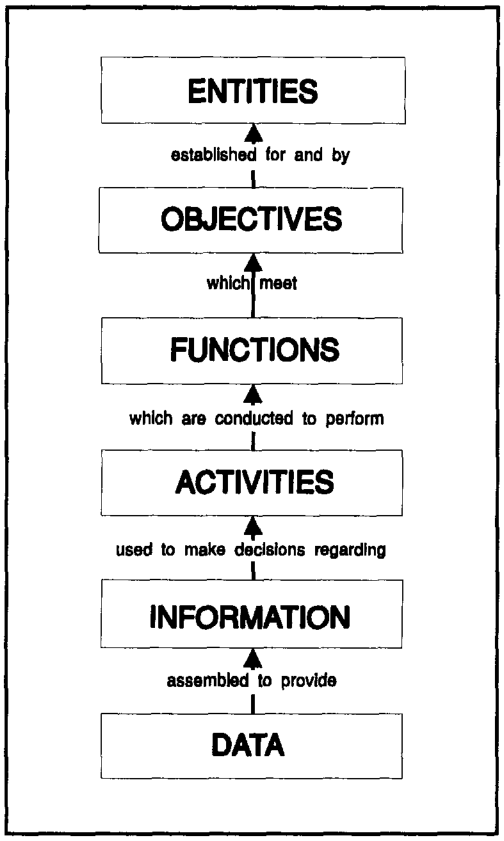


Figure 11
Flow of Information

As an example, the objectives of a State department of transportation include the design of safe highways. The highway engineering function, i.e., planning, design, construction, operation and maintenance of highways is required to achieve this objective. The activities include the development of design standards that reflect safety considerations. To arrive at those safe standards requires information on the relative safety of different highway geometrics. That information is generated by combining crash and roadway data with other data and performing the appropriate statistical analyses.

Traffic safety data uses. Figure 12 describes the functions that the highway safety data users perform which are likely to require the use of safety data. This list is not exhaustive, and the entities' reliance on safety data for their functions ranges from minimal to extensive.

The activities which are conducted by these data users can be grouped into five basic types as they relate to the use of traffic safety data:

1. Case Management - The handling of individuals, vehicles and other property associated with a single crash.

2. Problem Identification - Using safety information to determine the existence and nature of safety-related problems.

3. Countermeasure Selection - Using safety information to guide choices among alternative actions.

4. Program Evaluation - Using safety information as part of the information set to determine the effectiveness of an action or program.

5. Administrative - Using safety information to support planning and operational decisions of the entity.

Activities for which highway safety data are potentially useful. Combining the functions for highway safety data users and related types of activities provides more specific examples of what occurs within each of the entities. Figure 13 summarizes uses, with a focus on any use of safety data rather than on the extent of that use. The functions of the various entities frequently overlap or are otherwise replicated at different levels of government.

Not all entities will conduct all activities in performing various functions, nor will different entities conduct similar activities even though they may be performing the same function. In general, the safety management function and the legislative function may carry out activities which address any aspect of other functions. Research entities can also be employed in the performance of any of the functions.

Data User	**Functions of this User**
Law Enforcement Agencies	Enforcement of traffic laws (at all levels of government);
Traffic Safety Administration	Developing annual highway safety plans including program funding;
Highway and Public Works Departments	Planning, design, construction, operation and maintenance of highways;
Motor Vehicle Administrators	Licensing, registration and control of drivers and vehicles for highway use;
Medical Providers (EMS Systems/Hospitals)	Management and treatment of highway trauma including emergency response and plans for patient receipt;
Adjudication System	Administration of law to highway operation;
Legislators/Regulators	Enactment of laws and regulations to develop and control the highway system;
Insurers	Provision of insurance for road users;
Schools (Public and Private)	Training highway users;
Commercial Road Users	Commercial transport of goods, and public transport of people;
Vehicle Manufacturers	Design, manufacture and repair of vehicles; and
Independent Research	Examine causes of, and potential remedies for, crashes but not as a part of other entities here.
Other Interest Groups	Representation of special interests related to highway safety (National Safety Council, American Automobile Association, Motor Vehicle Manufacturers Association, Mothers Against Drunk Driving).

Figure 12
Users and Uses

Function	Case Management	Problem Identification	Countermeasure Selection	Program Evaluation	Administrative
Enforcement of Traffic Laws	a. Track prosecution of violators. b. Perform crash analysis and reconstruction. c. Provide court liaison and testimony. d. Request driver re-evaluations to propose license cancellations or revocations.	a. Analyze attributes of crashes and violators (for selective enforcement). b. Identify problem drivers, locations, environments, laws and regulations.	Choose from among alternative selective enforcement, traffic direction and control, public information, education, emergency medical service and/or escort programs and legislative or regulatory actions to impact suspected problems.	Determine appropriateness of terminating, modifying, or expanding existing programs.	a. Staff Resource Allocation - Determine the amount and schedule of personnel to perform duties and carry out programs. b. Implement selected programs. c. Support tort liability defense.
Administration of Highway Safety Programs		Analyze attributes s of crashes and violators, and identify problem vehicles, drivers, locations, highway features, laws and regulations.	Evaluate and/or select among administrative, highway engineering, enforcement, public information and education, medical, legislative, regulative and/or vehicle design strategies to correct suspected problems.	Determine appropriateness of adding, terminating, modifying and/or expanding existing programs.	
Planning, Design, Construction, Operation and Maintenance of Highways	a. Identify high-hazard locations. b. Determine needs for engineering action at specific locations (spots, segments and areas).	Evaluate and select among proposed alternative engineering actions, including alternative facility and network designs.	Evaluate the safety impact of changes in standards and practices, as well as recently implemented highway facilities and controls.		Support defense of tort liability actions.

Figure 13
Use of Highway Safety Data: Functions and Activities

Function	Case Management	Problem Identification	Countermeasure Selection	Program Evaluation	Administrative
Licensing, Registration and Control of Drivers and Vehicles	a. Provide driver and vehicle data to legal system. b. Conduct Hearings (where authorized). c. Examine and license drivers (e.g., use of "point" systems for violations and crashes). d. Assure financial responsibility. e. Track prosecutions. f. Provide court liaison and testimony.	Identify problem drivers (by attributes such as age, area of residence, type of vehicle driven, etc.).	Evaluate and select among alternative driver control and improvement actions (e.g., warnings, training, suspended license, revoked license, alternative sanctions), legislative and regulatory changes, enforcement activities and/or public information and education programs.	Evaluate the effectiveness of programs undertaken to determine if they should be modified, extended, or terminated.	
Management and Treatment of Highway Trauma	Evaluation and treatment of injuries to persons involved in traffic crashes, relating crash specifics to injury specifics.	a. Identify emergency response and trauma care system inadequacies and/or failures (e.g., response time, quality of diagnosis, quality of treatment, effectiveness of treatment, number of personnel, type and amount of facilities, and amount of associated costs).	Identify and evaluate alternative means for overcoming identified problems.	Evaluate the effectiveness of programs undertaken, to determine if they should be modified, extended or terminated.	

Figure 13
Use of Highway Safety Data: Functions and Activities (continued)

Function	Case Management	Problem Identification	Countermeasure Selection	Program Evaluation	Administrative
Management and Treatment of Highway Trauma (continued)		b. Identify vehicle, highway and human attributes which contribute to severity of injury, and degree of rehabilitation required.			
Administration of Law Applied to Highway Operation	Track and manage prosecutions and dispositions, as well as establish sanctions.	Evaluate operations and monitor performance of judiciary and other officers of the court.	Identify and evaluate actions to overcome identified problems (e.g., alternative sanctions, administrative adjudication, judicial and/or attorney training).	Evaluate the effectiveness of programs undertaken, to determine if they should be modified, extended or terminated.	Employ and schedule personnel and provide facilities to process cases in an efficient and just manner.
Enactment of Laws and Regulations to Develop and Control the Highway System		Identify policies, programs, regulations, legislation, funding levels, vehicles, and elements of the highway system which present hazards to the motoring public.	Identify and evaluate legislative and regulatory strategies to overcome the identified problems.	Evaluate the effectiveness of legislative or regulatory actions to determine if they should be modified, terminated or maintained.	
Provision of Insurance for Highway Users	Claims settlement and legal defense.	Identify vehicular and highway system problems which result in claims being filed, as well as identifying problem drivers.	Identify and evaluate alternative means for reducing claims frequency and amounts.	Evaluate the effectiveness of programs undertaken, to determine if they should be modified, extended or terminated.	Perform actuarial functions.
Training Highway Users		Identify patterns of driver attributes particularly associated with crashes.	Identify and evaluate alternative training content and methods to affect driver, pedestrian and bicyclist attributes. The focus will be on those attributes associated with crashes which, when corrected, have potential for reduction of crash frequency and severity.	a. Assess the effectiveness of driver training programs in enhancing highway safety. b. Evaluate the effectiveness of public information and education activities conducted in the school system.	

Figure 13
Use of Highway Safety Data: Functions and Activities (continued)

Function	Case Management	Problem Identification	Countermeasure Selection	Program Evaluation	Administrative
Transport of Goods and Public Transport of People.	Claims settlement and legal defense.	Identification by fleet managers (e.g., of large trucking firms, transit agencies, taxicab companies) of vehicular and driver problems which contribute to crashes and/or increase injury severity.	Identification and evaluation of fleet managers of alternative means of reducing crash frequency, severity and costs.	Evaluation by fleet managers of the effectiveness of programs undertaken, to determine if they should be modified, extended or terminated.	Assess actual and potential liability for fleet.
Design Manufacture and Repair of Vehicles.	Claims settlement and legal defense.	Identify vehicular problems which contribute to crashes and/or increase injury severity.	Identify and evaluate alternative vehicle design, manufacturing and/or repair actions for reducing crash frequency, severity and costs.	Evaluate the effectiveness of designs, practices and programs undertaken to determine if they should be modified, extended or terminated.	Assess actual and potential liability for design and manufacturing.
Independent Research	While much highway safety research takes place either within the other entities described above, or under contract to them, there is additional research conducted outside of the highway safety management system. Much of this research takes place at colleges and universities. Often the purpose of this research is to test a hypothesis and not necessarily to support management decisions. As such, the activities of this kind of research do not fit into the "case management, problem identification, etc." structure since the research is not necessarily oriented to a specific function.				
Representation of Other Interests Related to Highway Safety	Public and private interest groups exist for almost every aspect of highway safety. With regard to safety data, they may be considered similar to the highway safety management function. Current areas of emphasis for these groups include DUI, occupant restraint use, records systems, and vehicle design.				

Figure 13
Use of Highway Safety Data: Functions and Activities (continued)

6. Issues Affecting the Quality of Highway Safety Data

During the course of identifying how highway safety data were gathered and managed, the project team documented a number of issues raised regarding the quality of highway safety data. The issues affect costs, quality, safety, and protection of privacy often in combination. Resolution of the issues may involve expenditures or redirection of processes. However, any resolution often faces a conflict between the provision of safety data and the management of the incident which includes any case deriving from that incident.

Classification of Issues

The issues have been classified according to the first two phases of the highway safety information system, data collection and management, and by the sources of the highway safety data. The data-collection phase can be further divided into collecting data at the scene and away from the scene. Four components are of principal concern: crash data, medical data, roadway inventories, and Federal data bases. Table 10 shows 12 possible classifications for the issues based on phase and component. These classifications served as the framework for subsequent development of 76 issues.

Table 10
Classification Framework for Handling Highway Safety-Data

		Sources of Highway Safety Data			
		Traffic Crashes*	Medical*	Roadway Inventory	Totals
Data Collection	A. Collecting	11**	3	7	21
	B. Reporting	12	2	4	18
Data Management	C. Data entry and storage	16	8	3	27
Totals		39	13	14	66

* can be "on-scene" or "away-from-scene"
** values indicate the number of issues identified

Data collection is the phase of obtaining and recording data about the crash or roadway which will become part of the highway safety information system. Data about a vehicular crash may be obtained both at the scene and away from it. The latter activity is used to add facts that the investigators were not able to obtain at the scene. Much of the collection of trauma and related medical data, e.g., treatment, admittance, and outcome, are collected at the hospital or other treatment sites which are away from the scene.

Data management is the process of entering data into manual and automated files and maintaining those files. Where automated systems are used, data are entered into a database through keying, scanning, or image processing. What is stored should be available for those who require information about highway safety.

Issues Affecting Collecting and Reporting Data

Traffic crashes. After the responding officer has arrived, assessed the scene, and taken steps to stabilize the incident, he begins to collect and record data about the crash. These data will be used for case management and for crash safety reporting. In addition, the officer may leave the scene to collect additional data. The most common case is when the officer goes to the hospital to collect more information about injuries.

As the data are collected, the officer records them. The standard form is the police crash report (PCR) which contains information about the crash and serves for both case management safety data. The officer handling the crash, support officers, or special investigators, such as the accident reconstruction officer, may prepare supplementary reports. Generally, these reports are used for managing the case rather than for safety data. An exception would be the Fatal Accident Reporting System (FARS) analysts at the State safety agency who might used the supplemental reports for additional data required by the FARS database. Issues related to collecting safety data from crashes appears in figure 14. Figure 15 summarizes issues related to reporting those data.

Roadway inventory. Much of the data used by the roadway inventory is collected onsite and reflect the quality of that collection. Additional data come from construction and maintenance records. Generally these data are submitted to the State department of transportation where they are recorded on the roadway inventory file.

Tools used for collection range from handwritten forms to automated processes. Even with the automated process, there may not be verification built in during the collection of the data. One of the most common forms of collecting data is use of photologging whereby data are captured on film, videotape, or videodisc. These images may or may not be used to acquire data for the roadway inventory. Figure 16 addresses issues related to collecting and reporting roadway inventory data.

Medical information. Data related to injuries, initial handling of the victims, and treatment are recorded at the scene by emergency medical services (EMS) personnel, and at treatment sites (trauma centers, hospitals, and other medical facilities) by other medical personnel. The data can provide substantial information related to the potential causes of injuries, the treatment given, severity, and the prognosis for recovery.

Collecting Data - (at the scene of the crash) 1. Potential conflict among officer roles at a crash scene may degrade the quality of safety-data collected (roles noted in priority order): a. determine needs for further response b. stabilize scene to prevent further harm c. traffic control d. manage operations at the scene e. collect data for managing the case; begin in-depth investigation f. enforce traffic and other laws g. collect crash safety-data 2. Perceived need by officer to establish fault, for insurance and enforcement purposes, may bias the collection and interpretation of data 3. Inconsistent coverage of vehicular crashes yields biased samples and include - State and locally mandated reporting thresholds eliminate crashes, and - lack of police resources and motorists not reporting minor crashes to the police. 4. Incorrect use of resources may reduce quality of data collected resulting from: - lack of clearly defined roles for police at the scene, and - distractions while collecting and recording data. - multiple data gathering without proper communications of findings 5. Inaccuracy and imprecision in locating the crash, positions of vehicles and persons involved in the crash, and crash debris reduces usefulness of data for later analyses. 6. Collection of data *perceived by the officer* as having limited use will reduce the incentive to provide quality data. 7. Danger to officer at the scene reduces incentive to complete a thorough investigation of crash. 8. Inadequate initial and refresher training results in low-quality data gathering, as well as - limited feedback received by investigator, and - infrequent opportunities to investigate crashes 9. Adequate tools or means for collecting some of the data are not available, resulting in low quality including inaccurate or incomplete data. 10. Disturbance or destruction of the scene by traffic, fire, rescue, tow vehicle operators, as well as less well trained police officers.
Collecting Data - (away from the scene) 11. Needs for gathering additional data from vehicles and persons may affect completeness of crash report, particularly when data are required for case management. 12. Sources of data may not be readily accessible to the investigating officer because - extent of injuries and medical treatment are not available; - vehicles taken to different locations, and - reluctance of witnesses to be interviewed

Figure 14
Issues Related to Collecting Safety Data

1. Requiring officers to make judgements on matters for which they do not have adequate training will result in low-quality data, for example:
   - estimating speed, extent of damage, extent of injuries, and
   - determination of fault.
2. Care given to completing police crash reports often is directly related to the severity of the crash, resulting in inconsistent reporting.
3. Inadequate initial and refresher training results in low-quality data recording.
4. Poorly defined and inappropriate data elements and codes contribute to incomplete and inaccurate recording.
5. Even when comprehensive sets of codes are available for a given element, officers tend to select and use only a few.
6. Lack of codes or elements for specific needs results in loss of data.
7. Size and complexity of crash reports appear directly related to the likelihood of incomplete or inaccurate responses.
8. Reporting data which are also available from other sources or multiple recording of the same data increases the likelihood of inconsistency among data sources.
9. Completing report away from scene results in problems with accuracy and completeness because of failure to collect or forgetting data.
10. Review and quality control varies dependent upon attention and priority given to crash reporting by agencies.

Figure 15
Issues Related to Reporting Safety Data

Collecting Data

1. Lack of automated equipment to assist with collecting roadway data may result in inaccuracy, imprecision, and incompleteness in data collection.
2. Longitudinal geometrics (horizontal and vertical curvature) are not collected and will affect relating the crash to roadway characteristics
3. Roadway features may not be located accurately because of lack of proper measuring tools or assistance in measuring.

Reporting data

1. Limited feedback regarding accuracy of recording reduces the likelihood of collecting high-quality data.
2. Procedures for recording data are not available during construction and maintenance of roadways which affect quality.

Figure 16
Issues Related to Collecting and Reporting Roadway Inventory Data

An overriding issue affecting both EMS and trauma data is the lack standardized methods for recording them. Once recorded, there are few centralized repositories which can be used by the safety data community. Figure 17 lists issues with collecting data both at the scene and away from the scene, generally the hospital. Figure 18 shows issues related to reporting the data. In addition to the issues which specifically relate to handling of trauma data by EMS and hospitals, some of the issues related to collection and reporting of crash data also apply to medical information.

Collecting Data - at the scene of the crash 1. EMS personnel may not have information about the events leading up to the crash, deformations to involved vehicles, and location of persons in the vehicles limits later diagnosis of injuries. 2. Unavailability of correct names or accurate identifiers of injured persons precludes later attempts to match injured persons with a crash report. 3. Not all injured persons are seen or handled by EMS personnel.
Collecting Data - away from the scene 4. Inability to link patient with crash precludes associating injury data and treatment with crash facts. 5. Confidentiality of medical records precludes associating injury data and treatment with crash reports. 6. Classification of injuries is related to need for treatment and potential threat to life; it can not be related to the cause or outcomes, e.g. permanent disability. 7. Not all injuries are seen by medical units that might keep records of trauma-induced injuries.

Figure 17
Issues Related to Collecting Medical Data

1. Forms are not standardized, both at the EMS and treatment levels. 2. EMS reports may be completed after delivery of the injured to a medical installation and rely on the memory of EMS personnel for accuracy and completeness. 3. Reports may not be prepared for persons not transported by EMS personnel causing loss of data regarding injuries. 4. Multiple responding EMS agencies each may record differing data about persons treated in a specific crash.

Figure 18
Issues Related to Reporting Medical Data

Issues Affecting Data Management

Data management is comprised of two parts: entry and storage. Data entry involves the act of preparing data contained on reports for subsequent storage. The activity may involve microfilming or imaging, manual editing, distribution to various processing units, and the actual keying or scanning of the data themselves. Not all reports are entered into data bases, or if they are, the data bases may not be centralized. Medical data, particularly EMS forms, rarely are captured on a system.

During storage, data are maintained for later recovery and use. Data may be stored in paper files, as images on microfilm and computers, and digitally. The computer format may depend upon out-dated software or up-to-date, database management systems. They may be linked to images and to data residing in other data bases. Some States come close to having a distributed database system, at least at the State level. The crash safety-data may be linked to driver, vehicle, roadway inventory, and medical files. However, each file is maintained separately, and duplicate fields exist. No States currently integrate local data bases with the State files.

The most important issue affecting the quality and availability of data is costs. Upgrading systems, including the development of distributed systems is expensive. Few States have committed the necessary resources to upgrade their highway-safety management systems.

Traffic crashes. Data storage for traffic crash reports ranges from paper files at many police agencies to linked database systems in some States. Some State and local agencies also are introducing imaging systems to store reports.

Once completed and reviewed at the local level, the PCR is sent to the State safety agency for processing. An exception is reports which do not meet the reporting threshold established by the State. Some agencies also will record crash data on a local database, normally from the police copy of the PCR. Of the States visited only in Ohio does the local agency enter data directly to the State safety database.

After receiving the report, all States key data into the safety database. More than one agency may key data from the same report, some successively, others on a parallel path. Data may be entered at one time, or in two steps with some form of skeleton file being produced first. During entry, most States provide some form of manual review prior to keying the data. Many States have online editing systems which require correction of specific fields before the entry is accepted. Many States also use some form of batch editing to make corrections.

In addition to the computer database, local agencies and the States keep images of the documents on file. Most organizations keep a paper file. Many also will microfilm the crash reports. A few agencies are beginning to use imaging systems to maintain copies of the documents. The issues which affect management of crash data appear in figure 19.

Roadway inventory. Most roadway inventories studied in this project were not directly linked to crash safety data bases. As a result, information about locations on the roadway where crashes are occurring have to be matched manually to summaries from the crash safety database. Where locations of the crashes are not accurately coded (a problem in many States), the usefulness of the crash data is limited. Issues unique to roadway inventories appear in figure 20.

1. Local agencies enter data into their files prior to transmitting reports to the State, thereby increasing delay in availability at State level.
2. Maintenance of paper files can reduce flexibility in access and use of local data.
3. The number of steps required for handling reports increases delay and likelihood of errors.
4. Separation of duties for recording data allows differing levels of quality and timeliness at the State level.
5. Multiple data bases, particularly local and central, increase delays in data available centrally and increases handling of data.
6. Use of outdated database management systems reduce the likelihood of making changes and usually preclude linkages. They also can restrict the number of years of history maintained.
7. Editing is performed without access to original facts which limits ability to provide accurate and precise data.
8. Lack of automated assistance increases time required to process reports particularly for location coding.
9. A long period from crash occurrence until data are available from central source delays availability to users.
10. Paper files are the primary source of crash narrative and diagram limiting general availability of these two elements to of users who need them for specific crashes.
11. Variable confidentiality laws reduce availability of data to users.
12. State level processing not integrated with local level, reducing feedback needed for improving quality and quality assurance.
13. Change in forms without adequate review of entire process results in loss of data or quality of the data.
14. Lack of direct access by users reduces feedback needed to address quality as well as usefulness of data being recorded.

Figure 19
Issues Related to Data Entry and Storage - Safety Data

Medical information. Most data related to medical information from both EMS and trauma organizations are not maintained centrally. Several States have been taking steps to centralize these data. However, because of privacy laws and the threats of litigation, data may not be shared even though they are available from a central source. The CODES project currently being funded by the National Highway Traffic Safety Administration is seeking ways to associate data with crash reports and to make them available for users. Many of the issues related to traffic crash reports also are related to medical data. The issues which affect the management of medical data are shown in figure 21.

1. Not linked to State safety-database reduces precision of information to that base.
2. Roadway inventory does not reflect maintenance and construction changes reducing accuracy of inventory.
3. Crashes are not part of inventory thus reducing ability to access one source in order to determine relationship of crashes and roadway elements.
4. Lack of longitudinal geometrics (horizontal and vertical curvature) results in less complete information relating the roadway to the crash.
5. Accuracy and precision are variable, limiting usefulness of determining role roadway may have played in crash.
6. Lack of inventory for classes of highways reduces coverage.
7. Identification of roadway features imprecise because of measuring schemes.
8. Long intervals between times of updating the inventory will not reflect changes which may be related to increases or decreases in traffic crashes.

Figure 20
Issues Related to Data Entry and Storage - Roadway Inventory Data

1. Confidentiality of medical records limits the association of injury data and treatment with types of crashes.
2. Lack of data bases prevent single access to data and unavailability of data from many sources.
3. Medical data not available until after discharge or admitting creates long delays in availability of data.

Figure 21
Issues Related to Data Entry and Storage - Medical Data

7. Mission, Goals, Objectives, and Principles for a Highway Safety Information System

This chapter describes several key elements highlighting issues in the collection and management of highway safety data, as well as the identification and evaluation of strategies for improving highway safety data collection and management. The first part of the chapter defines the mission, goals, and objectives for the system. The second part lists a series of principles that should be applied to the system.

Mission of the Highway Safety-Data System

The highway safety information system operates within a larger system context. It is a subsystem of the highway safety decision making system, which in turn is a subsystem in the highway transportation system. This hierarchy continues, but it is sufficient to understand that the highway safety information system is one major information source in a broader setting.

The mission of the highway safety information system is to provide information to the decision maker in the manner most useful to support the decision being made. The functions which result from this mission include collection and management of highway safety data. The user should interact with the highway safety information system through a decision support system which can guide the user in the interaction with the information system.

Goals

Five goals have been identified within the mission of the highway safety information system. Each of these goals, in turn, has objectives which, when met, will constitute goal attainment. The goals apply to all safety data, including the crash, roadway inventory, and medical sources that are being focussed upon in this study. The goals for the operation of the highway safety information system are:

1. Minimize the costs of collecting and managing data.

2. Maximize safety in the collection of data:
   a. maximize the effectiveness of operation at the scene.
   b. minimize the exposure of involved parties.

3. Minimize effects on organizations, institutions, and operating systems.

4. Maximize quality of data for uses and users

5. Maximize suitability of data for uses and users

Goal statements tend to be general. To help make them operational, a set of underlying needs to be stated. These objectives need to be sufficiently specific that they suggest means for their achievement, as well as measures of effectiveness to determine the degree to which an objective has been achieved.

For each of these goals a set of objectives is described. As part of the evaluation, strategies which contribute to the goals will be measured against the objectives. A strategy may result in a positive outcome with one objective and a negative in another. Exhibit 3 depicts the manner in which goals, objectives, and strategies are employed to arrive at means for improvement of the highway safety data.

Objectives Identified for the Goals

Listed below, by goal, are a set of objectives considered applicable to the collection and management of highway safety data. Most of the objectives can be applied to all three sources of data upon which this project is focussing (crash reports, roadway inventory, and medical). A few will be applicable only to specific sources. That a specific source, rather than multiple sources, is addressed by a given objective, should not be considered a limitation.

I. Minimize the costs of collecting and managing the data

Costs incurred for collecting, reporting, and handling the data will be minimized. Included are costs of people, capital, and operations.

a. minimize costs of personnel required
   - direct and indirect costs
   - time spent collecting
   - time spent managing
   - time spent editing and reviewing

b. minimize costs of capital
   - equipment
   - materials

c. minimize the costs of operating the information system
   - development and replacement
   - maintenance

II. Maximize safety in the collection of data

The time taken to clear a crash scene and collect and record data, as well as the number of and exposure to persons involved is minimized. In addition, any process minimizes congestion.

1) Maximize the effectiveness of operation at the scene.

a. minimize time for response of appropriate personnel and equipment

b. minimize congestion at the scene
   - provide positive guidance through and around the scene
   - quickly clear the scene
   - rapidly restore scene to normal traffic flow

c. minimize time required on-scene to collect data

2) Minimize the exposure of involved parties.

a. minimize time subjects involved in or related to the crash remain at the scene

b. minimize number of officers and related safety personnel responding

c. minimize time safety personnel remain at the scene

III. Minimize effects on organizations, institutions, and operating systems

Organizations prefer status quo. Changes to the safety information system should, therefore, have a limited effect on organizations and their operations. Included are changes to processes, staffing, structure, and interference with other organizations, as well as time required to implement the process.

a. minimize changes to processing systems
   - new systems
   - revisions to current systems

b. minimize changes in staffing required to operate the system
   - number or persons
   - diversity of personnel clarifications

c. minimize changes to the organizational structure

d. minimize interference with other organizations

e. minimize the time required for implementation

IV. Maximize quality of data for uses and users

Six dimensions of quality are needed to reflect the complex needs of users. The attributes of consistency and coverage are measured over time, and coverage is also measured over geographical space.

a. maximize quality attributes (The individual elements listed below are defined and discussed in the section above entitled "Quality of Highway Safety Data.")
   i. accuracy
   ii. precision
   iii. timeliness
   iv. completeness
   v. consistency
      - among collectors and recorders (each collector records the data in the same manner with the same definition)
      - over time (data are collected based on the same definition over time)
   vi. coverage
      - by classification (all classifications, e.g. severity of crash, are completely covered)
      - over time (the same frequency of coverage occurs over time)
      - geographically (the same frequency of coverage occurs regardless of location of that coverage, e.g. the same data are gathered for local streets and expressways)
      - temporally

V. Maximize suitability of data for uses and users

A maximum number of cases are made available to the widest body of users. These users have easy access to the data with a maximum of technical support.

a. maximize the number of potential uses and users

b. maximize number of cases (sample-size) available for analytical purposes

c. maximize the ease of access to, and use of, data

d. maximize access to technical support

Principles for the Collection and Management of Highway Safety Data

Guiding the operation of the highway safety information system are general principles which are critical to the mission of acquiring appropriate data, managing them, and making them accessible to users. The principles apply to three dimensions of the safety information system: the system itself, people, and data.

The system:

- Comprehensive involvement of all participants, collectors, reviewers, data managers, and users.

- Provides ongoing monitoring, auditing, and evaluation, and feedback, as well as provisions for keeping it current.

- Crosses organizational lines and interacts with multiple files and sets of data.

- Subjects data to quality control as early in the collection and management process as possible.

- Provides for entry of data into the system as close to the point of collection as possible.

- Does not duplicate the collection of any data element within the system.

- Maintains identity of the source of each data element and record (e.g., identifies if crash report is a citizen report, desk report or officer field investigated).

Persons who work in the system:

- Are well trained and regularly updated in all aspects of the system, but especially in the one for which they are responsible.

- Are highly motivated, especially through job-related rewards.

- Receive regular feedback on performance, as well as usefulness of their efforts.

- Handle the minimum required data.

- Use data collection instruments which are easy to understand and manipulate.

- Are well equipped, particularly with automated assistance, including automated interview-assistance, preferably with expert system capabilities.

- Record the data using systems which require manual intervention only where automation cannot deal with it adequately, but which provide:
  - verification;
  - checks for errors;
  - corrections or avenues for correction.

- Edit and correct the data based upon access to the original facts of the case.

- Forward (transmit) findings immediately.

Data available to the system:

- reside in readily and easily accessible locations where each element resides in only one location, but is accessible to all others

- are available in a manner which is transparent and irrelevant to the managers and users

- reside in systems which are easy to maintain, modify, and link

- have an adequate and consistent history

- are overseen by an organization which is effective in performing its duties to maintain quality assurance for the collection, recording, analyses, entry, and maintenance of the data (generally the organization which has the greatest need for the data)

The goals and objectives set forth at the beginning of this chapter, when combined with the principles enumerated above, provide a context within which issues may be identified, and the strategies may be developed and evaluated, for improving the collection and management of highway safety data. The next chapter presents the strategies that have been identified.

8. Candidate Strategies for Improving Safety Data Collection and Management

Development of Strategies for Evaluation

As work progressed on the project, the need for improving collection and management of safety data became more apparent. The means for resolving most of the issues also became more apparent. The literature and site visits conducted as part of the project provided examples of many noteworthy practices which have been adopted in various agencies across the U.S. and elsewhere. These practices should be of interest to other State agencies. A summary of these noteworthy practices appears in the companion research report for this project.

The project team compiled an initial list of more than 45 strategies for improvement, many based on documented current practices. This chapter describes each of the candidate strategies and the next chapter describes their assessment.

Most of the strategies grew from considerations of how to affect the reporting and managing of traffic crash data. However, many of the same strategies also would help resolve issues related to roadway inventory and medical data. The strategies are organized according to the collection and management processes, with further subdivisions in each. Some of the data collection strategies relate to changing collection methods while others assist the collector. Data management is divided into process administration, data entry, and storage.

Table 17 at the end of the chapter lists all the candidate strategies. Their applicability to each of the three data sources is indicated therein. Further description of each strategy follows.

Data Collection - Change Methods (CC)

The strategies within this category have the common attribute that they involve a change in data collection methods.

1. **Telephonic reporting.** Reports of minor crashes and defects in the roadways can be telephoned to a central location.

   [crashes] Motorists will report all property-damage-only (PDO) crashes to the nearest police headquarters personally or by telephone. This step will require presence of trained personnel who can guide the involved person through the crash report.

A variation of this strategy requires officers to report crashes from the scene, using radio or telephone, to trained recorders. The recorders may be using standard report forms or computer-based devices to enter the data. The recorder could be trained as accident reconstructionist and interviewer to capture the most accurate data. The interview could be computer-aided or directed as well.

[roadway inventory] Crews can be used to report, via telephone, measurements and variations from the current record observed in the field. The central number to which they call can be staffed by persons trained to direct the field crews in appropriate procedures for measurement, and to perform quality control. The personnel at the central number can also handle calls, either from drivers wishing to report road faults or damages, or from police who, having investigated a crash, will want to make the highway authority aware of a condition that has changed as a result of the crash (e.g., damage to a barrier). While these changes may not be permanent, their existence may need to be noted in the record, especially if there is a likelihood that the condition may remain for a significant period of time.

2. **Use of sampling.** Sampling provides a mechanism for minimizing data collection effort while maintaining statistically valid data sets.

   [crashes] Through sampling, a selected set of crashes, for example, may be investigated in more detail than currently is done. The remainder of the cases are reported in less detail than others, or not at all. The detail in some of the samples may be even more than is currently provided. Lack of certainty regarding the true universe of crashes occurring makes this strategy problematic.

   [medical] For the medical data base, sampling can be used to provide deeper coverage on selected injuries. Trauma data bases normally are treatment-oriented rather than outcome-oriented. Sampling can be used to identify outcomes for injuries.

3. **Increase reporting thresholds.** Increasing the reporting threshold reduces the number of crashes which the police must report.

4. **Non-sworn crash investigator/Data collection specialists.** The specialist is one specifically trained in gathering the required data. That task is the person's primary function. Even though the person is considered a specialist, expenses can be relatively low because the agency is not using a more highly-paid person such as a sworn officer or highway engineer to perform the task.

   [crashes] Instead of using patrol or beat officers, trained non-sworn crash investigators would handle most crashes.

   [roadway inventory] For roadway inventory, staff can be hired and trained specifically for the purpose. If the agency currently uses engineers to collect and record the data, specially trained technicians could be less expensive.

5. **Use of non-automated (and automated) technologies.** Portable computers are being used for entry of data using automated processes for error trapping and upload to a data base. There are, however, several technological tools that can be employed to assist the collector that do not need to directly involve automated interfaces. These include video and audio recording devices, laser-based measurement devices, bar-code readers, and global-positioning system (GPS) receivers.

   [crashes] While the use of automated processing devices, such as small computers, can be effectively used in data collection, the scope of this project excludes consideration of those types of tools for crash reporting. Other non-automated technologies can be effectively employed, however. These include a bar-code reader or magnetic strip reader that produces output that can be read and recorded manually.

   [roadway inventory] One of the most promising current operations involves the use of computers. Technologically advanced measuring equipment can also be employed, whether or not they are directly connected to computers onboard. The computer can be used to present a real-time view of the roadway, based upon past data collection, to the collector as the person moves along the road. Resident or district engineers can also use computers to record data from construction plans and to correct them once the construction is completed. More advanced technology can also be employed for interpreting roadway video-logs through use of video image-processing techniques.

   [medical] Portable computers linked to patient monitoring devices will be of value both to emergency services personnel (EMS) and the trauma personnel. Photography, especially that which can be captured digitally, will also provide useful data for injury assessment and description. Driver licenses which have bar codes or magnetic stripes can be used to obtain information that a patient cannot provide under the circumstances. The devices can be either directly interfaced with computers or read from the devices output and manually noted.

6. **Common, Statewide EMS and trauma reporting form.** To help ensure capture of key EMS and medical data, all EMS and trauma personnel could be required to use forms which provide patient data for the safety information system.

7. **EMS collects all injury-related data.** The provision of all data related to type and extent of injuries and their potential causes can be made the responsibility of EMS personnel who are on the scene and treating the injured. The transmission of these data can be accomplished either by hard copy or via computer linkage to EMS systems.

8. **Must-move legislation.** Requires the removal of vehicles from the scene of a crash or disablement as soon as possible. Such legislation limits liability of police officers and support personnel for additional damage caused when trying to clear the scene expeditiously. This strategy is provided among the candidates primarily to reflect the need to protect those handling the scene, not to maximize the quality of safety data. The primary

objective is to reduce congestion at the scene of a crash, but it has potential impacts on the ability to provide quality crash data.

9. **More extensive supervisor review.** Supervisors would give all reports more intensive review. Blank spaces are not accepted; accuracy is verified. Errors, when detected, are returned promptly to for correction.

   [crash] Too much delay between the crash and return of the report for correction will mean that the original reporting officer may have forgotten many of the details and correction may not be possible.

   [roadway inventory] For the roadway inventory, similar steps are followed. The reviewer is responsible for ensuring that all attributes of quality are met.

10. **Review by specially trained personnel (local level).** Reports are reviewed at the local level by persons specially trained in crash analyses, or injuries and their treatment. The data collector and reporter can use notes rather than completing a specific form, although review of a completed form is also included here.

11. **Use of short-form and long-form reports.** Elements contained on the short form are collected for every crash reported by investigators. The long form contains additional elements which describe the crash, drivers, vehicles, environment, and injuries in a more comprehensive manner. This longer form is completed only when the crash severity exceeds a specified threshold (e.g. an injury or one of the vehicles required a tow as a result of damage sustained), or may be used in a sampling framework.

12. **Use of sworn crash investigators,** Instead of using patrol or beat officers, specially trained police crash investigators would handle most crashes. The police officer receives advanced training in crash investigation and carries all tools needed to perform the job.

Data Collection - Assist Collector (CA)

These strategies are designed to assist the collector in providing quality data in a cost-effective manner. They do not generally require changes in current forms and processes.

1. **Improved instruction manuals.** Many instruction manuals in use today are not very well conceived. They are often done as afterthoughts, with little time or budget available. Each responsible agency should prepare simple, graphic manuals which show how to investigate and report each element.

2. **Pre-printed diagrams.** Two types of pre-printed diagrams can be provided to facilitate improved diagrams and efficiency - generic and location-specific. Many crashes are similar in that they involve either a single vehicle striking a fixed object, or two vehicles in an angle, rear-end, or sideswipe collision. The officer can have available diagrams which cover these common occurrences, select the appropriate one, and add features and measurements. There will be intersections or other locations in any given jurisdiction which are complex. When crashes occur at these locations, officers will spend significant time on creating a good diagram, or will produce a very poor one.

3. **Simplified form design.** Simplifying the form can be accomplished by reducing the number of data elements collected as well as the number of codes within elements. Format of the form is also an element of this strategy.

4. **Revised/improved design and format.** The crash report is completely revised and redesigned to help guide the collection and recording of data. The goal is a form which is easier to read and complete, and reduces the need for reference manuals.

5. **Improved definitions of elements/codes.** A task force reviews each element and code based upon an analysis of how the codes have been reported, errors made, and evaluation of the codes by impartial third parties. The principal behind this strategy is equally applicable to the three data sources being studied.

6. **Priorities given to reporting.** Many law enforcement agencies have placed crash reporting low on their list of priorities because they perceive that the public wants agency resources primarily focused upon crime prevention activities. State highway patrols or State police are less affected in this manner than local agencies. This strategy calls for agency management to increase the priority of investigating and reporting crashes.

7. **Enhanced training.** Training for safety data collection is often either minimal at the start of an officer's career, or only available on-the-job. At the State level, the strategy would employ audit and training teams. Their responsibilities include first-time and recurrent training, and review of issues in crash reporting with individual agencies and officers. Ongoing training, where properly performed for all three of the sources under study, can provide appropriate support for improved quality.

8. **Collector incentives.** Quality reporting can be rewarded in a number of ways. Most common for law enforcement, for example, is preference given to the assignment of overtime. Other rewards such as additional training, choice of shift or assignments, additional time off, and even material awards, can be valuable. Rewards can be forthcoming from both the agency and State level.

9. **Interact with counterparts.** Personnel who collect and report the data can be provided opportunities to interact with others who perform similar functions in the same general geographic area. Cross-communication creates a sense of "community" which encourages collectors to act in a professional manner. Furthermore, it helps individuals identify how they can improve their performance, based upon others' experience. For both crash reporting and medical data collection, the State can oversee local task forces which attempt to identify important issues related to investigating crashes and using crash data. Officers can be selected because of quality reporting or on a rotating basis.

10. **Conferences and training programs.** The State can provide funds for selected collectors of safety data to attend conferences or special training sessions as a reward for outstanding reporting. This strategy is a more formalized approach than the one involving interaction with counterparts (which is designed to be a locally operated effort rather than a more centralized one).

11. **Field participation in forms design.** Collectors are selected to assist the State in ongoing redesign and updating of the PCR. They also can be responsible for testing as versions are developed. The strategy is equally applicable across all three sources under study. However, it is likely to have the greatest impact in crash reporting where police officers are involved.

12. **Lower wage personnel for data collection.** Instead of using expensive engineering personnel for all inventory work, roadway data can be updated on a regular basis through the use of persons working at lower wages. This may involve summer use of student labor (which may be available through a subsidized program).

13. **Common coding nationally.** Standards that have been developed for crash reporting on a national basis (e.g., ANSI, NGA and CADRE) would facilitate aggregate national studies. An important part of this strategy is that there be consistency in applying common definitions for the codes.

    [roadway inventory] No national reporting standards exist for reporting data on roadway inventory. The ANSI crash-reporting standards that apply to roadway attributes are of little use for roadway inventory purposes. The FHWA Highway Performance Monitoring System is a possible resource for initial ideas.

    [medical] The abbreviated injury scale has been proposed as a means of achieving national consistency in reporting injury severity. However, the coding system is oriented more toward supporting identification of appropriate treatment than for safety analysis.

14. **Computer directed interview (AI/expert systems).** One of the major issues identified in crash data collection is the number of judgements required of the collector (officer). A

computer-based interview format is a superior means for acquiring the data from the officer. If designed to be fully interactive with an expert system underlying it, the officer would receive a series of inquiries, each dependent upon the response to previous computer inquiries. Such systems help identify elements which need to be reported, dependent upon the type of crash, and help ensure completeness in collection of the quality data.

Data Management - Administrative (MA)

There are several administrative-level actions or activities that may be undertaken to improve the management of safety data. The phrase "administrative level" is meant here as those actions which involve upper levels of management in an agency.

1. **Security for privacy.** If data are to be made more accessible to users, security to prevent inappropriate access must be implemented. Particularly important is the security of medical data to prevent inappropriate or inadvertent invasion of privacy, yet allowing access to data for research.

2. **Quality-assurance programs.** Programs for quality assurance place emphasis on ensuring that data received are of high quality. Elements of this strategy include appropriate training and auditing of field work, editing of the data, and feedback regarding issues and high-quality work.

3. **Management support.** For data administration, management support includes a priority for maintaining activities that monitor and assess data quality and system effectiveness. It includes interaction with users to determine who are using data and how effectively the data can be accessed and used.

4. **System task force.** A task force is responsible for overseeing operation of the system. In this role, it reviews the process of collecting highway safety data, the data themselves, and the tools used in collection. It receives input from all persons associated with the system, including those collecting, recording, and coding the safety data, and the users. The group must oversee the relationships of the bases so that the data may be shared properly.

5. **Reorganization of management.** Managerial structure, particularly in regard to data base design and development, has evolved out of the single-organization, traditional vertical structure. As a result, the structure of managing the data must reflect the global nature of information along with being able to respond quickly to changes. Managing the highway safety information system would be more effective under a team that has authority to manage and maintain the system, not just one data base. Along with the team, a data administrator is needed who has a broader view and understands the role that data play in the overall picture.

Data Management - Data Entry (ME)

The establishment of a data base using data from such sources as field reports is a critical point in the processing of safety data. The procedures and tools used to enter the data into the data base can affect both cost and quality.

1. **Scannable forms.** Use optical mark recognition (OMR) and optical character recognition (OCR) to facilitate capturing data from the field reports. The introduction of these strategies will require revision of the classical field reports, particularly for OMR.

2. **Online and batch editing.** Introducing both online and batch editing as part of data entry has been found to produce high-quality data in an effective manner.

3. **Linked sources of data.** By linking sources of data which apply to crashes, including driver license, vehicle registration, roadway inventory, and medical data, fewer elements need to be gathered and coded by a collector of crash data. More importantly, the linked data bases can provide more data about an incident than had a single individual attempted to collect them.

4. **Local data entry.** Instead of forwarding all reports to a single source for data entry, the agencies which collect data also can enter them. When data are entered locally, the enterers usually have immediate and direct access to the collector in case there are questions or issues of interpretation.

5. **Imaging systems.** The translation of visual images to digital format of different types facilitates the management and access of data.

   [crash and medical] Instead of microfilming or filing paper copies of the data reports, the report itself becomes a digital image. The image can be called and scanned from multiple sources.

   [roadway inventory] Introduce technical equipment which can be used to interpret photographs and video material particularly for capturing distances and dimensions. The most immediate use of such technology would be for reading video logs taken of roadway features for the roadway inventory.

6. **Motivation and feedback.** The personnel performing data entry handle repetitive tasks, and are often faced with incomplete or poorly prepared reports. Use of various forms of motivation, feedback, and training can help these persons perform their jobs with greater satisfaction.

7. **Cross-training personnel.** By cross-training personnel, each person on the safety data base staff has an opportunity to perform tasks other than the one to which he is assigned. Doing other work provides a break from the repetition associated with data entry, location coding, etc.

8. **Sponsored elements.** Users of the data assume responsibility for various elements in the data bases. This can include elements which may only be collected and used by a small subset of the users. Responsibility for sponsored elements includes:

    - Developing the elements, their codes, and description of how to collect them.
    - Auditing their use and maintaining quality control.
    - Providing funding and/or other resources to collect the data.
    - Ongoing review of its need for inclusion.

9. **Comprehensive requirements for development and redesign.** Comprehensive design of a system includes the use of joint requirements planning (JRP) and joint application design (JAD), both of which are structured processes used in development. These procedures for design have been developed in the computer industry to provide a standard of quality for system design. The structured procedures help assure a comprehensive and effective system development. The process uses persons representing data gathers, recorders, and users.

10. **EMS/trauma data base.** Develop Statewide EMS and trauma data bases that can be used for safety analyses. Such a base requires the use of common reporting forms and training of the collectors and reporters. The trauma data base will maintain information about the nature and severity of injuries, presence of drugs and alcohol in the blood stream, other driver condition data, length of hospitalization, and outcomes from treating those injuries.

11. **Use of data analysts to interpret descriptive material.** This strategy relies least upon the collector as an interpreter. The collector and reporter record most of the data about a crash using narrative and a diagram. Personnel at a central location then interpret these items and complete the report. This is particularly useful for providing data about the manner of collision, sequence of events, and contributing causes. However, specially trained personnel also can receive EMS or other medical reports and interpret them according to the needs of the data base. In either case, the personnel are able to interpret the data, often more accurately and precisely than a general patrol officer.

Data Management - Storage (MS)

The system in which safety data are stored will determine to a large extent what flexibility and constraints will exist on the generation of information from it. This is largely a software issue but implies hardware functionality to operate the system.

1. **Relational data base systems.** For purposes of improved information management, particularly for local entry and open access to the data, the use of a relational data base is important. These are data bases which are made up of relations (a two-dimensional array of data elements) that has a data base management system which has the capability to recombine the data items to form different relations, thus giving great flexibility in the usage of data.

2. **Distributed data bases.** Distributed data bases allow for data to be maintained closest to their source while remaining available for aggregation to higher levels. Each source is designed and maintained by the organization which has responsibility for the related activities. Data are made available through communications links to other data bases, such as a highway safety data base. A distributed data base should have an open communications environment with relational data bases and multiple communications links.

3. **Object-oriented data base.** These data bases are created from "objects" which are sets of related descriptions and processes. Text and images can be accessed together and treated within a single data base.

4. **Centralized quality-control.** Quality control is used to help ensure that the data stored in the file are accurate, complete, and consistent. Design of standards should be done under centralized State leadership by a group of persons who represent the collectors, recorders, and users at all governmental levels. The standards must be directed to the level of quality needed by users, but not so difficult as to prevent collecting and storing data in a cost-effective and timely manner. The application of quality-control standards also necessitates ongoing review which can be performed by a quality-assurance team.

Table 11
Strategies for Improving Collection and Management of Data

Strategy	Crash Reporting	Roadway Inventory	Medical Services
Change Methods (CC)			
CC1. Telephonic reporting	x	x	
CC2. Sampling techniques	x		x
CC3. Increase reporting thresholds	x		
CC4. Non-sworn carsh investig./Data collection specialists	x	x	
CC5. Use of non-automated technology	x	x	x
CC6. Common, Statewide EMS/trauma reporting form			x
CC7. EMS collects all injury-related data	x		x
CC8. Must-move legislation	x		
CC9. More extensive supervisor review	x	x	
CC10. Review by specially trained personnel (local level)	x		
CC11. Use of short-form and long-form reports	x		
CC12. Sworn crash investigators	x		
Assist Collector (CA)			
CA1. Improved instruction manuals	x	x	x
CA2. Pre-printed diagrams	x		
CA3. Simplified form design	x		
CA4. Revised/improved design and format	x		
CA5. Improved definitions of elements/codes	x	x	x
CA6. Priorities given to reporting	x		

Table 11
Strategies for Improving Collection and Management of Data (continued)

Strategy	Crash Reporting	Roadway Inventory	Medical Services
CA7. Enhanced training	x	x	x
CA8. Collector incentives	x	x	x
CA9. Interact with counterparts	x		*
CA10. Conferences and training programs	x	x	x
CA11. Field participation in forms design	x	x	x
CA12. Lower wage persons for data collection		x	
CA13. Common coding nationally	x	x	x
CA14. Computer directed interview (AI/expert systems)	x		*
Management - Administration (MA)			
MA1. Security for privacy	x	x	x
MA2. Quality-assurance programs	x	x	x
MA3. Management support	x	x	x
MA4. System task-force	x	*	*
MA5. Reorganization of management	x	x	x
Management - Data Entry (ME)			
ME1. Scannable forms	x		x
ME2. Online and batch editing	x	x	x
ME3. Linked sources of data	x	x	x
ME4. Local data entry	x	x	x
ME5. Imaging systems	x	x	x
ME6. Motivation and feedback	x	x	x

Table 11
Strategies for Improving Collection and Management of Data (continued)

Strategy	Crash Reporting	Roadway Inventory	Medical Services
ME7. Cross-training personnel	x		
ME8. Sponsored elements	x	x	
ME9. Comprehensive requirements for development and redesign	x	x	
ME10. EMS/trauma data base			x
ME11. Use of data analysts to interpret descriptive material	x		x
Management - Data Storage (MS)			
MS1. Relational data base systems	x	x	x
MS2. Distributed data bases	x	x	x
MS3. Object-oriented data base	x	x	x
MS4. Centralized quality control	x	x	x

* These cells were considered to be the same as the crash reporting counter part and, therefore, not requiring separate analysis.

9. Assessing Strategies for Improving the Collection and Management of Highway Safety Data

Classification of Strategies for Evaluation

Forty six strategies were identified that are applicable to one or more of the three data sources being studied. Almost all of the strategies were applicable to crash data collection and management, while slightly more than 60 percent of the strategies were applicable to the other two data sources under study.

Before a final conclusion could be reached regarding strategies to recommend, the candidates needed to be assessed. The assessment was done in two steps. The first step involved a classification of the candidates into three types:

1. Those strategies that the project team believed to be sufficiently **proven** that they did not require further evaluation, especially because they did not require major investments or otherwise create significant concomitant impacts in the agency. These are strategies primarily derived from site visits. These are represented in the final evaluation results.

2. Those strategies which require **further evaluation** before they can be recommended to operating agencies. These strategies may have been used by several agencies, but may have sufficient impact on agency operations, especially in terms of cost, that the project team deemed it desirable to evaluate them further. These were the subject of additional assessment, as reported in this chapter.

3. Those strategies which require **further development** before they could be adequately assessed. These included strategies which were not sufficiently defined or definable, and for which there was limited experience. The concepts will need further definition and refinement or more field experience, before an adequate judgement could be made by the project team. Some of these could become subjects for future FHWA research efforts. Some are already subjects of research and demonstration programs. No further analysis or consideration of these is given here.

Methodology Employed for Strategies Requiring Further Evaluation

The objective was to assess the relative cost-effectiveness of the candidate strategies. In the absence of direct measurement of effectiveness criteria, the project team employed a structured rating system in conjunction with a set of application scenarios and outputs from the cost model.

Each of the strategies selected for further evaluation was assessed using a nominal rating system. Project team members rated each strategy on the basis of how well it would achieve the goals and objectives defined in a previous section of this report within the context of the eight scenarios to which the strategies would be applied. These scenarios, summarized in Figure 19, are presented in an appendix of the companion research report for this project. The scenarios were derived by the project team as their best representation of the range of users and uses. The development of the scenarios was based in part upon the earlier definition of users and uses for the data discussed above in this report.

Table 12
Framework for Scenarios

	Highway-Safety Component		
Application	Driver	Vehicle	Roadway
Site-Specific	#1 Police Selective Traffic Law Enforcement	#2 Commercial Vehicle Inspection for Overweight and Defective Equipment	#3 High-Hazard Location Identification
Systematic	#4 Use of Crash Data to Evaluate a Driver Improvement Program	#5 Effectiveness of Anti-Lock Brakes	#6 Changes in Crashes Related to an Increase in the Speed Limit

Note: Two additional scenarios were general in nature:

- Supporting a Budget Allocation
- Assisting with Defense in a Tort Liability Action

Assessment of the costs associated with each strategy was also performed using a nominal rating system. However, the cost model developed in Tasks A and B for crash report data collection and management was also used to estimate the effect of implementation and operating costs for those strategies applicable to crash reporting.

Five individuals associated with the project completed rating sheets for each strategy that had been classified as requiring further evaluation. These individuals are highly knowledgeable in the areas of safety data collection and management as well as experienced in a wide range of applications of safety data. Ratings were developed for each application scenario. These were combined across all scenarios and all raters. The strategies, all of which are considered cost-effective based upon the ratings, were combined with the proven strategies to arrive at a complete recommended set.

10. Conclusions and Discussion

Based on the assessment of the 46 strategies, several classifications were made based on cost effectiveness, length of time to implement, technological orientation, and by source of the data: crash reporting, roadway inventory, and medical data. These are summarized in figures accompanying the sections discussing each of the sources and numbered 20 through 21, and table 12. Within each figure the following classifications are described:

1. *Relative cost-effectiveness ranking* based on assumptions both about how much the strategy will contribute to improvement of the operation relative to its costs of implementation and operation. Effectiveness was rated considering the range of dimensions of quality, i.e., accuracy, precision, completeness, coverage, timeliness, and consistency. The groupings are relatively lower, moderate, and higher cost-effectiveness.

2. Short- vs. longer-term implementation reflecting two different time frames needed to implement the strategies.

3. Technological orientation which separates those strategies which were technologically oriented, from those that were not.

Crash Report Data

The longer-term strategies ranked as relatively highly cost-effective (figure 20) generally are designed to reduce or eliminate the role of the general patrol officer in the collection of crash data. This is done either through non-technological mechanisms which replace the general patrol officer with specialists, or by supporting the officer with improved tools. Data base strategies are designed to both reduce the amount of data that must be collected by officers and to minimize the handling of data at different levels of government. Imaging systems that employ OCR and OMR technology are considered effective means for cost reduction in the interim (5 to 10 years) until the majority of reports are completed on automated devices.

The formation of a system task force can be accomplished quickly and can be a foundational strategy which facilitates and supports many others. A well-conceived and structured task force can provide a foundation for most of the candidate strategies that have been identified. The other readily implementable, non-technological strategies that are ranked highly are primarily oriented toward simplifying the collector's job and encouraging them to do it well.

Table 13
Classification of Strategies for Collection and Management of Crash Report Data

	Relatively Moderate Cost-Effectiveness	Relatively Higher Cost-Effectiveness
Readily Implemented	cc3 - Increase reporting thresholds cc9 - More extensive supervisor review ca1 - Improved instruction manuals ca5 - Improved definitions CA7 - Enhanced training ca8 - Collector incentives CA9 - Interact with Counterparts ca10 - Conferences and training programs ma3 - Management support me7 - Cross training ME8 - Sponsored elements	ca2 - pre-printed diagrams ca3 - simplified form design CA4 - Revised PCR design MA4 - System task force me6 - Motivation and feedback
Longer-Term &/or Techno-logically Advanced	CC2 - Sampling CC10 - Review by specially trained personnel (local level) cc11 - Short and long forms ca11 - Field participation in form design MA2 - Quality-assurance programs *ME1-* ***Scannable forms*** *ME2 -* ***On-line & batch editing*** ME9 - Comprehensive requirements for Development ME11 - Use Data Analysts to Interpret *MS1 -* ***Relational Data base*** ms4 - Centralized quality control	CC4 - Non-sworn investigators *CC5 -* ***Use of non-automated technology*** CC12 - Sworn Crash Investigators *CA14 -* ***Computer directed interview*** *ME3 -* ***Linked data sources*** *ME4 -* ***Local data-entry*** *ME5 -* ***Imaging systems & OCR/OMR*** *MS2 -* ***Distributed data bases***

- Lowercase items numbers indicate classification is based upon interpretation of input received from operating agencies visited. Uppercase values are based upon ratings of effectiveness and results of cost projections using the project cost-model.
- No strategies were classified as having relatively low cost-effectiveness
- ***Bolded and italicized*** items are considered technologically advanced

The strategies ranked as having relatively moderate cost-effectiveness include some important means for improving quality and reducing costs associated with data collection and management. Many of the readily-implementable strategies in this group involve common sense actions, which would be implemented in any comprehensive improvement program. Most are related to training and education in different forms. The technologically-oriented strategies cover the gamut of impacts desired, including lower cost from scanning, better quality through comprehensive editing systems, and greater flexibility through use of relational data base designs. Quality-assurance and quality-control activities are included in this grouping. The impacts of these are probably the most difficult to project because it will be highly dependent upon the specific conditions under which they are implemented. The quality-assurance methods included in the candidate strategies involve use of regular computerized reports and monitoring of data quality by a dedicated quality-assurance team. Where current management systems include effective pre-processing systems and rudimentary batch-edit routines, the quality assurance effort will be less cost-effective than where these elements are not present.

Table 14 displays the strategies in order, ranked by the change in unit cost that was predicted using the cost model developed for the project. The associated cost-effectiveness is also shown for each strategy. The strategies that are predicted to result in a reduction of unit cost for collection and management of the data, are generally ranked with higher relative cost-effectiveness than those which involve an increase in unit cost. Notable exceptions to this are:

1. Motivation and feedback.

2. System task force.

3. Centralized quality control.

Roadway Inventory Data

The strategies ranked relatively high in cost-effectiveness (figure 21) focus on use of technology both for measurement and acquiring data to limit what must be collected in the field. Comprehensive system requirements, once established, will provide an important framework for developing a roadway inventory system that can be fully integrated with other systems.

The more moderately cost-effective strategies involve a combination of non-technological assists to the data collector, and the use of specialists instead of district engineers who have many other responsibilities. Strategies directed to data management tend to focus upon technological approaches, either to reduce labor costs or to institute improved data base designs. While the technological strategies are considered to be relatively effective, they also have relatively high costs associated with their implementation.

Several of the strategies ranked with relatively low cost-effectiveness focus upon activities designed to encourage or educate the data collector. Since the collector of roadway data is directly accountable to the people who use the data, this is considered enough incentive to do a good job. Furthermore, if the person collecting the data is doing this as a low-priority task which is not part of their basic job description, it is not likely to affect that person's performance review. In this case, time taken for training may be viewed as interference with the person's job. Furthermore, small incentives may be meaningless to such a person.

Quality-assurance programs and centralized quality-control were rated relatively low. However, this is highly dependent upon the specific conditions in the agency, as discussed in the section above.

Table 14
Effect of Strategies on Unit Cost of Collecting and Managing Crash Data

Index No.	Description	Change in Unit Cost %		Rating of Relative Cost- Effectiveness
CC11	Use of short-form and long-form reports	-11%	Reduced Unit Cost	◗
CA2	Pre-printed diagrams	-6%		●
CA3	Simplified form design	-6%		●
CA4	Revised/improved design and format	-6%		●
ME3	Linked sources of data	-6%		●
CA14	Computer directed interview (AI/expert systems)	-6%		●
ME5	Imaging systems	-6%		●
CC4	Non-sworn crash investig./Data collection specialists	-5%		●
MS2	Distributed databases	-5%		●
ME1	Scannable forms	-4%		◗
CC5	Use of non-automated technology	-3%		●
CA1	Improved instruction manuals	0%	Neutral Effect on Unit Cost	◗
CA5	Improved definitions of elements/codes	0%		◗
ME4	Local data entry	0%		●
CC12	Sworn crash investigators	0%		●
MA3	Management support	0%		◗
CA11	Field participation in forms design	0%		◗

Table 14
Effect of Strategies on Unit Cost of Collecting and Managing Crash Data (continued)

Index No.	Description	Change in Unit Cost		Rating of Relative Cost- Effectiveness
		%		
ME7	Cross-training personnel	1%	Increase in Unit Cost	◗
CA8	Collector incentives	1%		◗
ME6	Motivation and feedback	1%		●
ME8	Sponsored elements	1%		◗
MA4	System task-force	1%		●
CC9	More extensive supervisor review	1%		◗
CA9	Interact with Counterparts	2%		◗
ME2	Online and Batch Editing	2%		◗
CA7	Enhanced training	2%		◗
CC2	Sampling techniques	2%		◗
MS1	Relational database systems	2%		◗
CA10	Conferences and training programs	3%		◗
ME9	Comprehensive requirements for development and redesign	3%		◗
ME11	Use of data analysts to interpret descriptive material	3%		◗
MA2	Quality-assurance programs	5%		◗
CC3	Increase reporting thresholds	5%		◗
CC10	Review by specially trained personnel (local level)	5%		◗
MS4	Centralized quality control	5%		●

●= Relatively Highly Cost-Effective ◗ = Relatively Moderately Cost-Effective

Table 15
Classification of Strategies for Collection and Management of Roadway Inventory Data

	Relatively Lower Cost-Effectiveness	Relatively Moderate Cost Effectiveness	Relatively Higher Cost-Effectiveness
Readily Imple-mented	CC1 - Telephone reporting ca8 - Collector incentives ca10 - Conferences and training programs me6 - Motiviation and feedback MS4 - Centralized quality control	cc9 - More extensive supervisor review ca1 - Improved instruction manuals ca5 - Improved definition of codes CA7 - Enhanced training ma3 - Management support	
Longer Term &/or Techno-logically Advanced	CA12 - Use of minimum wage field-personnel MA2 - Quality assurance programs *ME2* - ***Online/batch editing***	CC4 - Data collection specialists ca11 - Field participation in forms design *ME4* - ***Local data entry*** ME8 - Sponsored elements *ME11*- ***Imaging & OCR/OMR*** *MS1* - ***Relational data bases*** *MS2* - ***Distributed data bases***	*CC5* - ***Use of Technologies*** *ME3* - ***Linked data sources*** ME9 - Comprehensive system requirements

- Lowercase items numbers indicate classification is based upon interpretation of input received from operating agencies visited. Uppercase values are based upon ratings of effectiveness and results of cost projections using the project cost-model.
- ***Bolded italicized*** items are considered technologically advanced

Emergency Medical Data

The relatively higher cost-effectiveness rankings for strategies (table 12) to improve emergency medical data fall mostly with longer-term technological applications. These are primarily designed to improve data management, both through linkage and reducing labor intensive activities. However, these are nicely combined with complementary activities on the collection side which designate the better-trained EMS personnel to collect injury data needed for safety analysis. The other selected strategies provide those personnel with better training and tools to simplify their job and make them effective providers of data for those outside the medical system as well.

The strategies ranked relatively moderate in cost effectiveness are less technologically oriented than the previous group. They focus on form design, quality assurance, and improved data base technology.

The strategies having a relatively lower cost-effectiveness ranking involve, in the short term, basic support for the collector and those managing the data. For the longer run, national uniformity was not considered relatively cost-effective, nor was the use of special interpreters. The latter was because the personnel in the emergency medical area are generally highly trained. On-line editing appears with relatively low rank because fairly effective manual editing is assumed extant.

Grouping of Strategies

Since the strategies represent a broad range of activities at different levels of investment and for different parts of the system, it is important to consider how they can be combined for overall better results than if implemented individually or in an uncoordinated manner. In fact, some of the strategies are interdependent, some are inclusive of others, and some are mutually exclusive of others. The relationship between the various strategies is demonstrated in Table 17. The

Table 16
Classification of Strategies for Collection and Management of Crash Report Data

	Relatively Lower Cost-Effectiveness	**Relatively Moderate Cost-Effectiveness**	**Relatively Higher Cost-Effectiveness**
Readily Imple-mented	ca1 - Improved instruction manuals ca5 - Improved definitions of elements & codes ca8 - Collector incentives ma3 - Management support me6 - Motivation & feedback	ca9 - Interaction with counterparts ca10 - Conferences and training programs ME4 - Local entry	CA7 - Enhanced training
Longer-Term &/or Techno-logically Advanced	CA13 - Common coding nationally *ME2* - ***Online & batch editing*** ME11- Analysts to interpret and code reports	CC6 - Common Statewide form ca11 - Field participation in forms design MA2 - Quality assurance programs MS1 - **Relational data base** MS2 - **Distributed data bases** MS4 - Central quality control	CC2 - Sampling techniques *CC5* - ***Use of technologies*** CC7 - EMS collect all injury data *ME1* - ***Scannable forms*** *ME3* - ***Linked data sources*** *ME10* - ***EMS/trauma data base*** *ME5* - ***Imaging and OCR/OMR***

- Lowercase items numbers indicate classification is based upon interpretation of input received from operating agencies visited. Uppercase values are based upon ratings of effectiveness and results of cost projections using the project cost-model.
- ***Bolded and italicized*** items are considered technologically advanced

stronger relationships are indicated through symbols. The blank cells also are indicative of a positive yet not strong relationship. A symbol was not used to avoid cluttering the table. There are symbols, however, which indicate mutual exclusivity, i.e., where the two strategies are inappropriate to be practiced together.

The strategies ranked relatively moderate in cost effectiveness are less technologically oriented than the previous group. They focus on form design, quality assurance, and improved data base technology.

The strategies having a relatively lower cost-effectiveness ranking involve, in the short term, basic support for the collector and those managing the data. For the longer run, national uniformity was not considered relatively cost-effective, nor was the use of special interpreters. The latter was because the personnel in the emergency medical area are generally highly trained. On-line editing appears with relatively low rank because fairly effective manual editing is assumed extant.

The table is designed for the user who, although focusing upon a specific issue (e.g., use of non-sworn crash investigators) can quickly scan across to identify highly complimentary strategies. Examples include: relieving the investigator of reporting injury severity by assigning that responsibility to EMS personnel, and re-organization of management to ensure that leadership is directed toward the new group rather than just being an added responsibility of an already overloaded administrator.

Applicable Principles

The set of principles enumerated above, entitled "Mission, Goals, Objectives and Principles for a Highway Safety Information System," should be considered important findings. Although they were presented at the earlier point of this document to support the development of strategies, they have a broader, more fundamental, value.

Table 17
Relationships Between Strategies

	CC1 Teleph. Reporting	CC2 Sampling	CC3 Increase Thresh-olds	CC4 Non-sworn Investig.	CC5 Non-auto mated Technol.	CC6 Common EMS Form	CC7 EMS Collect Injury	CC8 Must Move Legisl.	CC9 Extens. Superv. Review	CC10 Compltn by Trained Persnl.	CC11 Short & Long Forms	CC12 Sworn Investigs.
CC1. Telephonic reporting	—									O	O	
CC2. Sampling techniques		—									●	O
CC3. Increase reporting thresholds	O		—									
CC4. Non-sworn crsh invetig./Data collection specialists				—	O		O					
CC5. Use of non-automated technology	☮			O	—				O	O		O
CC6. Common, state-wide EMS/trauma reporting form					O	—			O	O		
CC7. EMS collects all injury-related data					O	●	—		O	O		
CC8. Must-move legislation								—				
CC9. More extensive supervisor review						O	O		—	☮		
CC10. Completion by specially trained personnel (local level)				O		O	O		☮	—		O
CC11. Use of short-form and long- form reports		O							O	O	—	
CC12. Sworn crash investigators					O		O		O			—
CA1. Improved instruction manuals						O	O					
CA2. Pre-printed diagrams	☮					☮	☮					
CA3. Simplified form design	O				O	O	O		O	O	O	
CA4. Revised/improved design and format	O				O	●	O		O	O	O	
CA5. Improved definitions of elements/codes						O	O		O	O		
CA6. Priorities given to reporting	☮	☮	☮	O	O	☮	O		O	O	O	O
CA7. Enhanced training				O		O			O	O		O
CA8. Collector incentives	☮			O		☮	☮		O	O		O
CA9. Interact with counterparts				O								O
CA10 Conferences and training programs				O			O					O
CA11 Field participation in forms design				O		O						
CA12 Minimum wage persons for data collection	O	☮	☮	●	O	☮	☮	☮	●	☮	☮	☮
CA13 Common coding nationally				O	O	O	O				O	O
CA14 Computer directed interview (AI/expert systems)							O					
MA1. Security for privacy												
MA2. Quality-assurance programs				O	O				✔	✔		O
MA3. Management support									O	O		
MA4. System task-force						O	O					
MA5. Reorganization of management												
ME1. Scannable forms				O		O			O	O		O
ME2. Online and batch editing									O	O		
ME3. Linked sources of data						O	O					
ME4. Local data entry									O	O		
ME5. Imaging systems												
ME6. Motivation and feedback				O								O
ME7. Cross-training personnel												
ME8. Sponsored elements												
ME9. Comprehensive rqrmnts for development and redesign												
ME10 EMS/trauma database						O	O					
ME11 Use of data analysts to interpret descriptive material				O		O	O			✔		O
MS1. Relational database systems						O						
MS2. Distributed databases						O						
MS3. Object-oriented database												
MS4. Centralized quality control				O	O	O			O	O		O

Table is to be read horizontally. That is, each row is the referenced strategy and each cell in the row indicates the relationship of the other strategy to it.

● The presence of the strategy above is necessary, or extremly important, to the success of the referenced strategy.
O The presence of the strategy above is important, or very useful, to the success of the referenced strategy.
✔ The referenced strategy is a subset of the strategy above.
☮ The two strategies are usually inappropriate to be practiced together, or it is not applicable

Table 17
Relationships Between Strategies (continued)

	CA1 Imprvd. Instrucn. Manuals	CA2 Pre-Printed Diags.	CA3 Simplified Form Design	CA4 Revised Form Design	CA5 Improved Defs.	CA6 Priority to Reportg.	CA7 Enhanced Training	CA8 Collector Incentives	CA9 Interact with Others	CA10 Confs. & Trng. Progs.	CA11 Assist in PCR Design	CA12 Minim. Wage Collecrs.	CA13 Common National Coding	CA14 Computer Directed Intervw.
CC1. Telephonic reporting	O	O	O	O		⊗	O	O			O	✔		●
CC2. Sampling techniques	●			●		⊗	●	O	O	O		⊗		
CC3. Increase reporting thresholds						⊗						⊗		
CC4. Non-sworn crsh invetig./Data collection specialists	O					✔	O		O	O				⊗
CC5. Use of non-automated technology	O						O							
CC6. Common, state-wide EMS/trauma reporting form	O	⊗	⊗	⊗	O	⊗	O		O	O	O	⊗		O
CC7. EMS collects all injury-related data		⊗	⊗	⊗	O	⊗	O	O	O	O		⊗		
CC8. Must-move legislation												⊗		
CC9. More extensive supervisor review			O			✔	O					⊗		
CC10. Completion by specially trained personnel (local level)			O			✔	O					⊗		
CC11. Use of short-form and long- form reports	O		✔	✔	O	⊗	O				O	⊗		O
CC12. Sworn crash investigators	O					✔	O		O	O		⊗		
CA1. Improved instruction manuals	---					✔								
CA2. Pre-printed diagrams		---		O										
CA3. Simplified form design	O		---	✔	✔		O				O	⊗		O
CA4. Revised/improved design and format	O		✔	---	✔		O				O	⊗		O
CA5. Improved definitions of elements/codes	●				---		●				O			O
CA6. Priorities given to reporting	O		O	O	O	---	O	✔			O	⊗		
CA7. Enhanced training			O		O	O	---							
CA8. Collector incentives						O		---	O	O	O	O		
CA9. Interact with counterparts							O	O	---	O	⊗	⊗		
CA10. Conferences and training programs	O					O		O	✔	---	⊗			
CA11. Field participation in forms design			✔	✔	✔	O		O	O	O	---			
CA12. Minimum wage persons for data collection	●	⊗	⊗	⊗	●	⊗	●	O	⊗	O		---		⊗
CA13. Common coding nationally	●		O	●	✔		●	●	O	O			---	O
CA14. Computer directed interview (AI/expert systems)	●			●	●					O	O	⊗		---
MA1. Security for privacy														
MA2. Quality-assurance programs	O	O			O	O	O	O		O		⊗		
MA3. Management support								O				⊗		
MA4. System task-force											O	⊗		
MA5. Reorganization of management														
ME1. Scannable forms	O		O	●			O				O	⊗		⊗
ME2. Online and batch editing	O			O	O									
ME3. Linked sources of data														
ME4. Local data entry	O		O	O	O		O							
ME5. Imaging systems		O												
ME6. Motivation and feedback						✔		●	O	O	O	⊗		
ME7. Cross-training personnel	⊗	⊗					●					⊗		
ME8. Sponsored elements				●	O									
ME9.														
ME10 EMS/trauma database		⊗	⊗	⊗	O	⊗				O		⊗		
ME11 Use of data analysts to interpret descriptive material	O	O	O	O	O		O			O		⊗		⊗
MS1. Relational database systems					O									
MS2. Distributed databases					O									
MS3. Object-oriented database		O		O										
MS4. Centralized quality control					O									

Table is to be read horizontally. That is, each row is the referenced strategy and each cell in the row indicates the relationship of the other strategy to it.

- ● The presence of the strategy above is necessary, or extremly important, to the success of the referenced strategy.
- O The presence of the strategy above is important, or very useful, to the success of the referenced strategy.
- ✔ The referenced strategy is a subset of the strategy above.
- ⊗ The two strategies are usually inappropriate to be practiced together, or it is not applicable

Table 17
Relationships Between Strategies (continued)

	MA1 Security for Privacy	MA2 Quality Assurance Progs.	MA3 Mgmt. Support	MA4 System Task Force	MA5 Reorg. of Managmt.	ME1 Scan-nable Forms	ME2 Online & Batch Editing	ME3 Linked Data Sources	ME4 Local Data Entry	ME5 Imaging Systems	ME6 Motivn. & Feedbk.	ME7 Cross Trng. Persnl.	ME8 Sponsrd. Elements	ME9 Compre. Reqmts.	ME10 EMS/ trauma Database	ME11 Data Analysts Interp.	MS1 Relanl. DB's	MS2 Distributd. DB's	MS3 Object Orientd. DB's	MS4 Centralzd. Quality Control
CC1. Telephonic reporting		O						O	O			O								
CC2. Sampling techniques																				
CC3. Increase reporting thresholds																				
CC4. Non-sworn crsh invetig./Data collection specialists		O	O		O															
CC5. Use of non-automated technology				O																
CC6. Common, state-wide EMS/trauma reporting form		O		O		O		O		O										
CC7. EMS collects all injury-related data		O	O	O			O	●		O		⊗	⊗	⊗						
CC8. Must-move legislation																				
CC9. More extensive supervisor review		✔	O												⊗					
CC10. Completion by specially trained personnel (local level)		O													⊗	⊗				⊗
CC11. Use of short-form and long- form reports			⊗	O											⊗					
CC12. Sworn crash investigators		O	O												⊗					
CA1. Improved instruction manuals				O																
CA2. Pre-printed diagrams																				
CA3. Simplified form design				O				O							⊗	O				
CA4. Revised/improved design and format				●		O		O							⊗					
CA5. Improved definitions of elements/codes		O		O			O	⊗					O	O						
CA6. Priorities given to reporting			●	O										O						
CA7. Enhanced training			O																	
CA8. Collector incentives		O	O								✔									O
CA9. Interact with counterparts		O	O																	
CA10. Conferences and training programs		O	O	O							O									
CA11. Field participation in forms design			O	O																
CA12. Minimum wage persons for data collection						⊗						⊗			⊗	⊗				
CA13. Common coding nationally		O		O			O													O
CA14. Computer directed interview (AI/expert systems)				O			⊗	●		O				●	O		O	O	O	
MA1. Security for privacy	—			O				O						O	O		O	●	O	
MA2. Quality-assurance programs		—	●	O			✔	●			✔									✔
MA3. Management support			—	O	O															
MA4. System task-force			●	—	O															
MA5. Reorganization of management			●	O	—															
ME1. Scannable forms				O		—				O					⊗					O
ME2. Online and batch editing							—	O	O	O		O		O			O	O	O	O
ME3. Linked sources of data			●	O				—		O				●	O		●	O		
ME4. Local data entry			O	O		O	O	O	—	O		O		O			O	O		
ME5. Imaging systems				O		●				—				O						
ME6. Motivation and feedback		O	O								—									O
ME7. Cross-training personnel			O									—			⊗					
ME8. Sponsored elements			O	●	O								—		⊗					
ME9. Comprehensive rqrmnts for development and redesign			O	●	O									—	⊗					
ME10 EMS/trauma database			●	O				O		O		⊗	⊗	⊗	—		O	O		O
ME11 Use of data analysts to interpret descriptive material								O								—	O			
MS1. Relational database systems			O	●				✔						O			—			
MS2. Distributed databases			O	●				●						O			●	—		
MS3. Object-oriented database			O	●		O		O		O				O			O		—	
MS4. Centralized quality control			O	O	O		O	O				O					O			—

Table is to be read horizontally. That is, each row is the referenced strategy and each cell in the row indicates the relationship of the other strategy to it.

● The presence of the strategy above is necessary, or extremly important, to the success of the referenced strategy.
O The presence of the strategy above is important, or very useful, to the success of the referenced strategy.
✔ The referenced strategy is a subset of the strategy above.
⊗ The two strategies are usually inappropriate to be practiced together, or it is not applicable

Further Research and Demonstration Needed

Throughout this project a number of aspects of the topic have been identified as items requiring further study. The level of study can be divided simply into demonstration and research. Many of the strategies recommended here have demonstrated their effectiveness because they are currently in use in one or more operating agencies. However, not much has been done to stronger relationships are indicated through symbols. The blank cells also are indicative of a positive yet not strong relationship. A symbol was not used to avoid cluttering the table. There are symbols, however, which indicate mutual exclusivity, i.e., where the two strategies are inappropriate to be practiced together.

Field evaluations. Strategies are not implemented in a vacuum, and usually not as a single measure (except where the strategy is really a composite of several sub-strategies). Therefore, field evaluations should seek to implement a "package" of strategies. Each package should have an underlying theme or core. Examples of themes include:

1. Replacement of the general patrol officer as a crash reporter in urban and suburban areas.
2. A basic redesign of the crash report.
3. A basic redesign of the data base management system.
4. A comprehensive quality-assurance program.
5. Complementing a well-designed and operating collection and management system by applying advanced technology throughout the process.
6. Reducing requirements for crash data reporting an absolute minimum (without losing needed data).
7. Providing complete longitudinal geometrics in the roadway inventory data base.
8. Creating a roadway inventory history data base.
9. Use of EMS personnel to collect injury severity and driver condition data in a form suitable for highway safety analyses, without using "blind" matching (i.e., as being done under the CODES project).
10. Localizing data entry and data management.
11. Implementing major reorganization to more effectively direct and control the data collection and management process.

12. Achieving maximum inter-connectivity of, and minimum duplication between, safety data bases.

13. Developing and implementing a comprehensive and continuing effort to train safety data collectors, using state-of-the-art training techniques (to demonstrate the real potential of adequate training).

Each of these "themes" can involve several, if not many, of the strategies that have been suggested. The specific combination will be highly dependent upon conditions in the jurisdiction involved. The ideal approach would be to package strategies considered highly complementary, applying them to a site that has an appropriate base condition. The evaluation would involve developing and quantifying measures of effectiveness designed to address issues of cost, quality and institutional or organizational impacts.

Research. A complementary research effort is needed to investigate some strategies and issues more fully before FHWA can suggest other new or improved strategies for agencies to try. Research needed includes:

1. Identifying ways for a jurisdiction to estimate the degree of coverage of crashes of various types, how they vary over time and with respect to other variables, and how an agency can use that information to adjust its evaluation designs, analytical methods, and decision making.

2. Further study of the strategies identified as requiring more development.

   a. Telephonic reporting
   b. EMS collects all injury-related data
   c. Must-move legislation
   d. Priorities given to crash reporting
   e. Common national coding of crash data
   f. Security for privacy
   g. Reorganization of management
   h. Object-oriented data base

Any of the items in this list could be addressed whether through FHWA or NHTSA research programs, or jointly.

3. Expand current FHWA efforts to study emerging technologies to include (possibly using the current FHWA program for traffic records technology application and demonstration):

   a. Data base management (e.g., advanced data bases, advanced communications)

b. Roadway inventory data collection (e.g., using satellite imaging and instrumented vehicles, especially to obtain longitudinal geometrics, and to maintain current conditions). This area is also a topic of study under a recently advertised NCHRP project (Number 15-15).
c. Use computer-based interviews for crash and medical-data collection (including possible application of expert systems)
d. Ongoing projections and monitoring of technological advances to allow early experimentation (e.g., satellite imaging, data from intelligent-vehicles)

Conclusion

The results of this project indicate that safety data collection and management is a complex process which is being relatively well conducted in many State and local agencies in the U.S. It is clear, however, that improvements in data quality and cost-effectiveness of systems will be required to meet the requirements of limited resources and to maintain and improve the usefulness of the data for those who seek to produce safer highways. A variety of strategies have been identified as potentially useful to agencies. While the relative cost-effectiveness of any one or a combination of these has been assessed here in a generic manner, the attributes of a particular agency will cause the cost-effectiveness experience to vary. The findings reported here provide a good starting point for agency self-assessment, planning and decision making. Users of this report are encouraged to study Exhibit 40 carefully, as it provides a relatively detailed, but succinct, summary of the possible combinations of strategies that might be considered.