CRASH DATA COLLECTION AND ANALYSIS SYSTEM

Final Report 537

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DISCLAIMER

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16. Abstract

The Arizona Department of Transportation (ADOT) is responsible for ensuring the safety and operational efficiency of Arizona's state highways. Fulfilling that responsibility requires extensive data collection and analysis, which are very labor-intensive resource-intensive. Seeking to identify how the agency could accomplish the greatest service improvements with the most efficient use of funds, ADOT engaged ARCADIS to perform a Crash Data Collection and Analysis study and examine the possibilities offered by technological innovations such as Electronic Data Entry (EDE), Relational Database Management Systems (RDBMS), and Geographic Information Systems (GIS). The study resulted in a comprehensive report with three components: an examination of best practices in use in the United States today, a use case and gap analysis examining ADOT's current data work, and a technical memorandum outlining how changes could be implemented. Together, the three parts point to a path to introduce best practices in ADOT's crash-analysis systems. Adopting the best practices outlined can reduce the resources required to maintain these systems, freeing those resources to other safety-related concerns.

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SI (MODERN METRIC) CONVERSION FACTORS*

APPROXIMATE CONVERSIONS TO SI UNITS					APPROXIMATE CONVERSIONS FROM SI UNITS				
Symbol	When You Know	Multiply By	To Find	Symbol	Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH					**LENGTH**		
in	Inches	25.4	millimeters	mm	mm	millimeters	0.039	inches	in
ft	Feet	0.305	meters	m	m	meters	3.28	feet	ft
yd	Yards	0.914	meters	m	m	meters	1.09	yards	yd
mi	Miles	1.61	kilometers	km	km	kilometers	0.621	miles	mi
		AREA					**AREA**		
in^2	square inches	645.2	square millimeters	mm^2	mm^2	Square millimeters	0.0016	square inches	in^2
ft^2	square feet	0.093	square meters	m^2	m^2	Square meters	10.764	square feet	ft^2
yd^2	square yards	0.836	square meters	m^2	m^2	Square meters	1.195	square yards	yd^2
ac	Acres	0.405	hectares	ha	ha	hectares	2.47	acres	ac
mi^2	square miles	2.59	square kilometers	km^2	km^2	Square kilometers	0.386	square miles	mi^2
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fl oz	fluid ounces	29.57	milliliters	mL	mL	milliliters	0.034	fluid ounces	fl oz
gal	Gallons	3.785	liters	L	L	liters	0.264	gallons	gal
ft^3	cubic feet	0.028	cubic meters	m^3	m^3	Cubic meters	35.315	cubic feet	ft^3
yd^3	cubic yards	0.765	cubic meters	m^3	m^3	Cubic meters	1.308	cubic yards	yd^3
	NOTE: Volumes greater than 1000L shall be shown in m^3.								
		MASS					**MASS**		
oz	Ounces	28.35	grams	g	g	grams	0.035	ounces	oz
lb	Pounds	0.454	kilograms	kg	kg	kilograms	2.205	pounds	lb
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		ILLUMINATION					**ILLUMINATION**		
fc	foot candles	10.76	lux	lx	lx	lux	0.0929	foot-candles	fc
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2	cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE AND PRESSURE OR STRESS					**FORCE AND PRESSURE OR STRESS**		
lbf	Poundforce	4.45	newtons	N	N	newtons	0.225	poundforce	lbf
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa	kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

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

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GLOSSARY OF ACRONYMS

ADOT	Arizona Department of Transportation
AIDW	ADOT Information Data Warehouse
ALISS	Accident Location Identification Surveillance System
ATIS	Arizona Transportation Information System
ATSIP	Association of Transportation Safety Information Professionals
BIA	Bureau of Indian Affairs
CAD	Computer-Aided Dispatch
CCT	Closed-Circuit Television
CODES	Crash Outcome Data Evaluation System
CRASH	Collision Report Analysis for Safer Highways
DMV	Department of Motor Vehicles
EDE	Electronic Data Entry
EDT	Electronic Data Transfer
FARS	Fatality Analysis Reporting System
FHWA	Federal Highway Administration
FMS	Freeway Management System
GIS	Geographic Information Systems
GPS	Global Positioning System
HCRS	Highway Conditions and Reporting System
ISTEA	Intermodal Surface Transportation Efficiency Act
ITCA	Inter Tribal Council of Arizona
ITS	Intelligent Transportation System
MAG	Maricopa Association of Governments
MVD	Motor Vehicle Division
MMUCC	Model Minimum Uniform Crash Criteria
NHSA	National Highway Safety Act
NHSDA	National Highway System Designation Act
NHTSA	National Highway Traffic Safety Administration
PDA	Personal Digital Assistant
QA/QC	Quality Assurance/Quality Control
RDBMS	Relational Database Management Systems
RWIS	Road Weather Information System
SHL	State Highway Log
TADS	Traffic Accident Data System
TEA	Transportation Efficiency Act
TIS	Traffic-Interchange Signal
TraCS	Traffic and Criminal Software
TRB	Transportation Research Board
VMS	Variable-Message Signs

EXECUTIVE SUMMARY

The Arizona Department of Transportation (ADOT) is responsible for the safety and operational efficiency of Arizona's state highways. Fulfilling that responsibility requires extensive data collection and analysis, which are labor-intensive and resource-intensive. Seeking to identify ways the agency could accomplish the greatest service improvements with the most efficient use of funds, ADOT engaged ARCADIS to perform a Crash Data Collection and Analysis study and examine the possibilities offered by technological innovations such as Electronic Data Entry (EDE), Relational Database Management Systems (RDBMS), and Geographic Information Systems (GIS). The study resulted in a comprehensive report with three components: an examination of best practices in use in the United States today, a use case and gap analysis examining ADOT's current data work, and a technical memorandum outlining how changes could be implemented. Together, the three parts point to a path to introduce best practices in ADOT's crash-data analysis related database systems. Adopting the practices outlined below can reduce the resources required to maintain these systems, freeing those resources to other safety-related concerns.

BEST PRACTICES

To identify the states whose system components can be considered best practices ARCADIS conducted a survey. Based on the survey results, leading states were selected for more in-depth analysis. The research team examined five components of each selected state's crash-data analysis system: data collection, data storage, analysis and reporting, accessibility, and overall system efficiency. The best innovations within each component were then combined to form an ideal system that would maximize efficiencies for any crash-data system, including ADOT's.

Some states have proven that electronic, field-based data entry and electronic data transfer (EDT) can expedite data entry and increase efficiency. Reducing data entry points and electronically transferring data increase data consistency and accuracy through the use of data element standards and business rules for validation and quality assurance/quality control (QA/QC). The use of an open RDBMS provides great flexibility in data accessibility and analysis. Direct links to outside databases such as facility, citation, drivers' license, and vehicle registration databases are beneficial.

The ideal configuration of analysis and reporting components varies with needs, but ADOT should target specific functions and capabilities. Among them:

- The ability to generate custom reports and queries from a centralized location that optimizes efficiency for end-users and managers.
- User-friendly GIS capabilities that integrate mapping and spatial analysis into reports.
- Easy access to and downloading of previously generated reports.
- The ability to perform advanced statistical analysis and charting by pulling data directly from the enterprise database to ensure that the most current information is used.

- A Web-based application for data retrieval and analysis that provides the greatest data access to the most users.

USE CASE AND GAP ANALYSIS

A use case study is a multi-level research that identifies current desires, assets, capabilities, and workflows for a particular organization. A gap analysis discovers where the current system falls short of best practices. Among the conclusions:

- Arizona should utilize electronic, field-based data entry and electronic data transfer. Those processes should use domains and business attribute rules for automated QA/QC and standardization of data elements. X,Y coordinates of accident locations should be determined and recorded from the Global Positioning System (GPS) or Geographic Information Systems (GIS) with every incident record to improve accident positional accuracy. External database systems, such as vehicle registration and driver's license databases, should be integrated into an enterprise system of transportation-related databases to minimize data entry. Personnel at crash scenes should collect more Model Minimum Uniform Crash Criteria (MMUCC) data elements, including harmful events[1]. The user community should standardize data elements for street naming and crash definitions. Signalized intersection and road contract release dates[2] should be collected and maintained.

- Arizona should integrate additional data sources to the Accident Location Identification Surveillance System (ALISS). The State Highway Log (SHL) system should be the primary source of facility information that is attached to the incident record, allowing statewide average of incidents to be calculated by facility. The current ALISS lacks detailed system documentation and the ability to manipulate the database structure as well as a visual data entry form to accommodate any changes in the future.

- Arizona should automate its data reporting and data exporting routines, giving users direct access to a live crash-data analysis system and allowing them to analyze the data and generate custom reports for export. On-line functions should include GIS, advanced statistical analysis, and graphic and charting capabilities. This on-line access point should be built as a one-stop access point for data and analysis and should include access to digital ALISS reports. The system should also be designed to automatically submit data to the Federal Highway Administration (FHWA) and Fatality Analysis Reporting System (FARS). It should allow users to:
  - generate statewide averages of accidents by facility type.

[1] Harmful events are defined as a series of related incidents within an accident or a crash. For example, in a car crash one car rear-ends another car and the struck car then runs into a third car. Then, this car crash will have two harmful events, the first involves the first and second cars and the second involves the second and third cars. First, second, third harmful events and so on indicate the order of the incidents that occur within an accident. Of all the harmful events involved in an accident, most harmful event is the most severe incident that causes the most damage or injury.

[2] A Contract Release Date is the official date on which a highway agency takes control of the road or intersections maintenance from a construction contractor and open the road for traffic.

- generate lists of top ten accident locations for a given area by facility type.
- identify high-risk/hazardous locations.
- assess the effectiveness of improvements
- calculate accident and severity rates over identified stretches of highway
- draw diagrams using Intersections Magic.

Basic and user-friendly GIS diagramming and mapping should also be functional.

- Arizona should grant access to its crash-data analysis system to all users within the crash data community through an Internet-based application and a one-stop portal for data access and analysis. A 24/7 solution would provide the greatest access and flexibility for end users.

- Arizona needs to eliminate redundant data entry. On-line and customizable data downloads, centralized access to tools and data, and live linkages for custom reporting will minimize staff intervention at all levels.

A use case study delves into the specifics of an organization, resulting in a broad and complete understanding of its business practices. For the ADOT study, a combination of interviews and data analysis defined current assets and capabilities. ARCADIS visited ADOT's facilities and interviewed several key players responsible for crash data, as well as people at external entities such as the Federal Highway Administration (FHWA), regional governments, and local municipalities.

Three areas were identified as critical for appropriately defining ADOT's business practices. These were internal desires, existing assets and capabilities, and workflows. The internal desires section of this report identifies the current desires expressed by the various users of ADOT's systems and data. The desires are apportioned among the five components used to identify best practices: data collection, data storage, analysis and reporting, accessibility, and overall efficiency. The existing assets and capabilities section gives an overview of ADOT's current systems, databases, GIS capabilities, analytical tools, reporting tools, and data-sharing. The workflows identify data flow and timeframes for getting these data to and from ADOT systems.

TECHNICAL MEMORANDUM

The technical memorandum of this report proposes solutions to the desires and gaps identified during the earlier portions of the study. It lays out specific course of action to reduce the resources ADOT must allocate to collect and analyze crash data. The strategy aims at delivering the most capability for the least funding while building toward an ideal crash data collection and analysis system.

Step 1 – Creation of a new ALISS database

To accomplish the goals set forth in the previous portions of the study, a new database system must be devised to store and retrieve incident records. Generating accident and severity rates, analyzing safety improvement effectiveness, and prioritizing accident locations by facility type all require linking the ALISS and ADOT Information Data

Warehouse (AIDW) databases. Unfortunately, the current ALISS is neither documented nor customizable, making it difficult to establish this linkage. Either funding needs to be applied to the ALISS to document it and make it customizable, or a new system needs to be developed. The project team recommends creating a new ALISS based upon a GIS system and using an RDBMS and ArcSDE. This will provide the basis for a relationship between the AIDW and the ALISS while utilizing software capabilities already in place within ADOT. The new ALISS will need a new interface for data entry and minimal training for current data-entry staff. Once the database is created, the records in the current ALISS must be migrated to the new system.

The new system should take advantage of MMUCC standards for data elements with the understanding that not all elements are currently collected in the field. As more agencies move toward electronic data entry, the ability to collect additional MMUCC elements may become available. The database should be designed to incorporate this possibility. The data elements of first, second, and most harmful events should also be incorporated. This change will require an alteration of the accident data collection form.

The existing stored reports in the current ALISS will need to be migrated to the new system. These reports are very important to the crash data community as a whole, and the system would be taking a step backward if they were lost in the conversion.

Step 2 – Integrate the new ALISS with the current GIS infrastructure and the data warehouse

ADOT GIS is undergoing a migration to a new geodatabase data structure for maintaining roadway information. This system is linear-referenced with dynamic segmentation and is capable of storing a variety of facility information in the relational database scheme. The project team recommends integrating the ALISS with the new GIS roadway database and the AIDW. This will provide all facility information in a GIS format that can be analyzed with the new ALISS.

Steps one and two are the most important aspects of this implementation plan and should be performed concurrently to maximize interoperability and minimize cost.

Step 3 – Create Electronic Data Transfer (EDT) routines

ADOT is duplicating a significant amount of effort by not accepting electronic transfer of incident records. Several municipalities type incident records into a database system in their offices, only to then send a hard copy to ADOT for entry into the ALISS. The project team recommends that ADOT accept EDT and create import routines and workflows to support this initiative. This will involve a study to determine all the possible data import formats in the systems that the various agencies use for their incident records. The team believes that there are probably only five or six different systems in use and the creation of the import routines should only require minimal effort. Each record should contain the same data elements, minimizing the complexity of creating the import routines.

Step 4 – Create web access to integrated databases for data query and download

Staff resources are required to distribute ALISS data to users both within ADOT and externally. This can be eliminated by utilizing existing software within ADOT GIS. ArcIMS is a Web-based application that allows display, query, and download of GIS data through the Internet at a user's discretion. When the ALISS is integrated with the AIDW and the ADOT GIS database, users can access data through the ArcIMS Website. Basic GIS functionality is inherently available to all users who have access to the Website. This will also provide live access to the ALISS, ensuring that users get up-to-date information for their analyses. ArcIMS can be designed to only display and export information that is not sensitive, or a security system can be implemented to grant or deny users access to sensitive data.

Step 5 – Accident and severity rates database

With the linkage among the ALISS, AIDW, and GIS databases, accident and severity rates can be calculated for facility types by numerous factors, including vehicle type, driver's age and gender, weather condition, and geography. These rates should be incorporated into a database for all to use. This database can be created without staff involvement other than routine database administration. Once the database is built, updating the rate values can be automated. These calculations are relatively simple within a GIS system and can be provided through the ArcIMS Website with minimal effort. A study should be undertaken to decide which rate calculations will be made available, including rates by time and geography (i.e. weekly, monthly, yearly by county, ZIP code, region, by facility, type, age, weather, etc.). The study will drive the database design, the number of execution statements required, and the frequency of the rate updates. The rates will then be tied to the appropriate highway GIS features for inclusion into the overall system for users to analyze. This database feasibility is currently being researched by the Maricopa Association of Governments (MAG) and its progress should be monitored.

Step 6 – Additional data collection efforts

All analytical capabilities start with good data resources. The collection of data about signalized intersections, contract release dates, and safety improvements would grant users analytical capabilities that they currently do not have. Most of these data should already be maintained by various agencies, including ADOT, and need only to be found and integrated into the GIS system. Some of these data demand more resource to be integrated than others, but the level of effort deeded for the data integration cannot be quantified until the data resources can be found and analyzed.

Step 7 – Electronic data entry

It would be optimal for the state to embrace electronic data entry for all incident records. This may not be feasible due to financial limitations, but ADOT should promote its use whenever possible in the hopes that eventually this will become a reality.

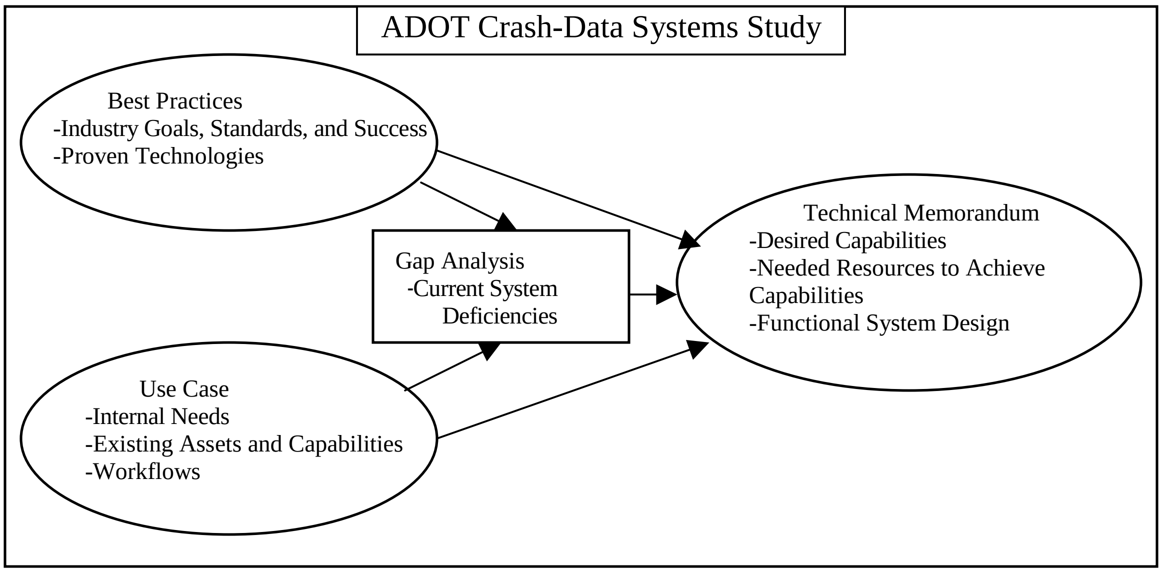

Figure 1. Crash-Data Systems Study – Project Design

1. INTRODUCTION

The Arizona Department of Transportation (ADOT) is responsible for the safety and operational efficiency of Arizona's state highways. Additionally, the National Highway Safety Act (NHSA) of 2003 mandates that ADOT collect and report crash information. All levels of government use this information in analyses to identify areas where safety is a critical concern and improvements could be made, and to measure the overall effectiveness of the safety improvements. The crash data-collection techniques and analytical processes are very labor-intensive and resource-intensive. They place a significant burden on budgets, especially during times of dwindling financial resources.

ADOT engaged the services of ARCADIS for a Crash Data Collection and Analysis study to develop alternatives to mitigate some of these intensive processes through technological innovations such as electronic data entry (EDE), Relational Database Management Systems (RDBMS), and Geographic Information Systems (GIS). To help identify the most appropriate and cost-beneficial solutions for ADOT, a multi-part study was proposed with the following objectives:

- to identify and research current ADOT databases and systems to leverage existing information assets to support crash data analysis.

- to identify internal and external users' need for crash data and analysis to support their safety-analysis functions.

- to determine ADOT's current processes for collecting crash data and documenting workflows.

- to research the industry's current crash data analysis best practices for application at ADOT.

- to define system requirements (data, procedures, tools, and applications) for use by ADOT and local jurisdictions to effectively identify, analyze, map, and report crash information and safety enhancements.

- to develop and present an implementation plan for improving crash data collection and analysis.

To achieve these objectives, this comprehensive study was produced with three report products (Figure 1). The first component of the study was a Best Practices review of other states' crash systems. This highlights some of the most efficient and technologically advanced systems in use around the country. The best practices of these states served as a benchmark for ADOT to meet or surpass in developing or improving its own systems. The second component was a Use Case study and Gap Analysis. The Use Case was an in-depth study of ADOT's desires and current system components of ADOT's existing crash systems. Once ADOT's current systems were defined and its desires and goals were identified, a gap analysis highlighted the deficiencies of the current system and the steps needed to bridge the gaps between the existing and proposed systems. The final portion of the study was a Technical Memorandum listing specific steps and resources required to implement the output from the Gap Analysis.

The result of this three-part study is the steps necessary to introduce best practices in ADOT's crash-analysis systems and, as a result, reduce the resources required to maintain these systems and allow resources to be reallocated toward additional safety-related concerns.

2. BEST PRACTICES

This section of the study used a research-based approach to determine how leading states handle crash-data systems and to report on the benefits of their techniques. The innovative and efficient practices identified serve as benchmarks to which ADOT can aspire in migrating its crash data systems.

2.1 INTRODUCTION

In 1991, the Intermodal Surface Transportation Efficiency Act (ISTEA) required states to have highway safety management systems (Section 1034), with a goal of reducing the number and severity of traffic crashes. In 1995, the National Highway Systems Designation Act (NHSDA) made the implementation of safety management system and other selected management systems optional, while maintaining the required reporting. TEA 21 (1998) and subsequent reauthorizations still require that basic crash-data be compiled by each state. They also require data uniformity so data can be exchanged between states and compared.

While states must comply with this legislation, each state has a different method of compliance. Each state has been given the flexibility to control its own crash-data system, and thus there are 50 different crash-data systems. Standardization efforts span multiple states, but each state has its own needs and its system can be remarkably different. This, however, creates wonderful possibilities for ADOT to learn from other organizations. To help realize these possibilities, this best practices review has been undertaken to examine each state's system.

To help identify the states that have system components that can be considered best practices, the research team conducted a survey. This survey asked questions designed to highlight efficient and innovative practices in crash-data systems. From the survey results, leading states were selected for more in-depth analysis of the factors that make their systems stand out as best practices. The team examined each selected state for five components: data collection, data storage, analysis and reporting, accessibility, and overall system efficiency. The best innovations within each component were then combined to form an ideal system that would maximize efficiencies for any crash-data system.

2.2 METHODOLOGY

To determine the best practices of each of the 49 states surveyed, the research team selected a Web-based electronic survey method. After a contact list for the 49 states' Transportation Departments was compiled, an e-mail was sent inviting each state to respond to questions about its existing crash data system (see Appendix A for survey questions). The data gathered was for descriptive statistical analysis only, due to the qualitative nature of a number of the questions. The descriptive data was analyzed to initially gauge a state's current status and then to narrow down the list to a few states that were considered to have the best practices. The analysis method of the survey was a unique-case orientation. Each state's attributes were compared for data collection, data

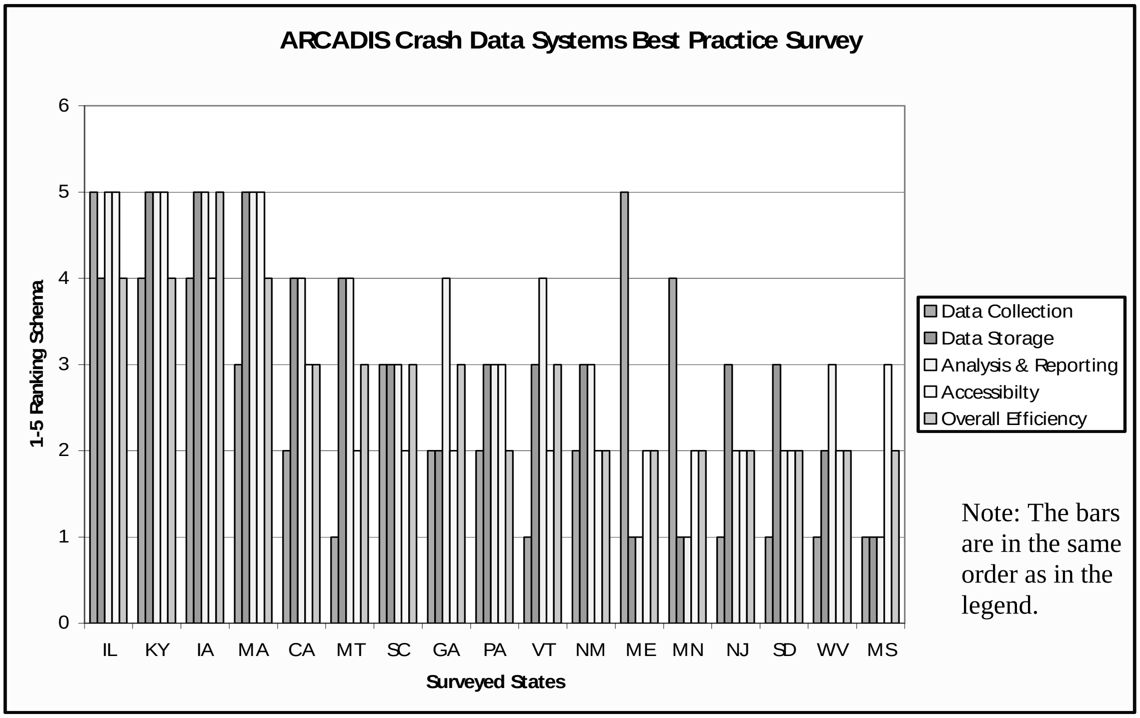

Figure 2. Best Practice Survey Results – State Rankings per Category

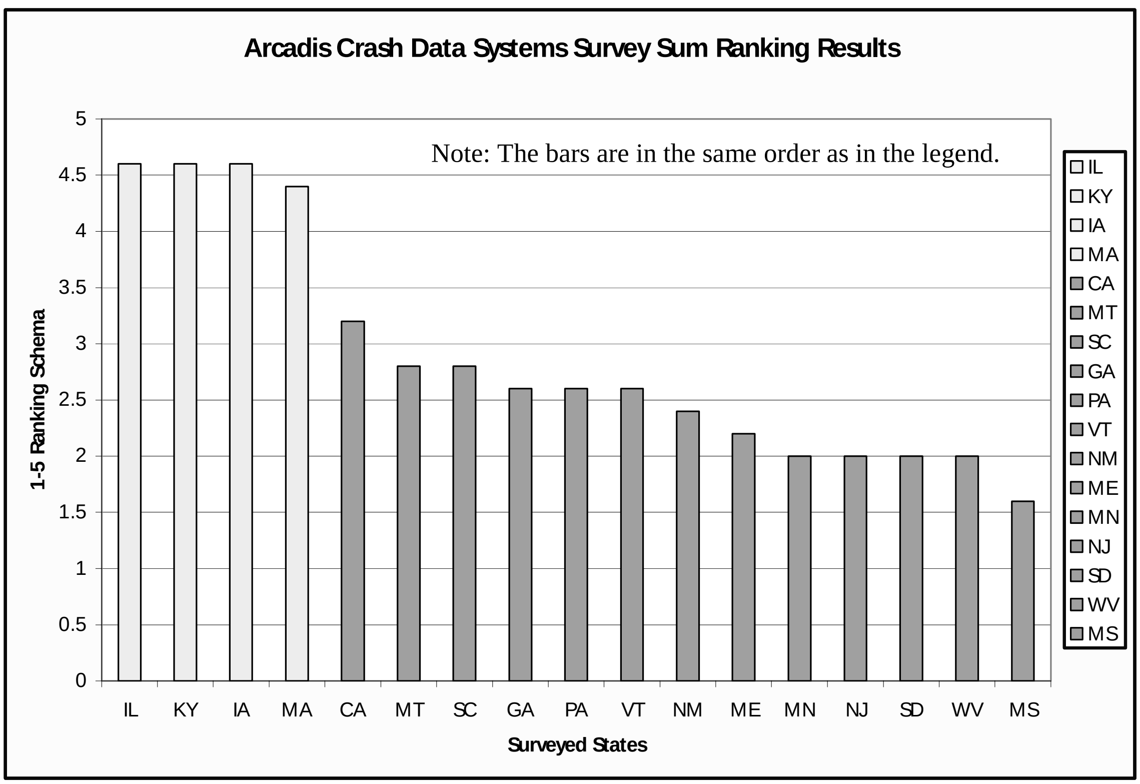

Figure 3. Best Practice Survey Results – State Rankings Overall

storage, analysis and reporting, accessibility, and overall efficiency. The newest implementation date and years in service as well as the use and innovation of new technologies were weighting factors. The ranking schema follows an order of 1 being the lowest score and 5 the highest. Data collection rank was determined by 5, representing new technology such as GPS, electronic data submission and by the standardization of data entry, and 4-1, representing the degree to which this technology was lacking and the status of any new system to replace the old methods. Data Storage was ranked 1-5 where 5 represents the utilization of a customized Oracle database system and 1 represents the maintenance of and dependence on a mainframe system. Analysis and Reporting was ranked by 5 representing the use and design of technological innovations, such as an enterprise management system and GIS, and 1 representing manual or disconnected applications procedures, which were deemed labor intensive and redundant. Accessibility was ranked 1-5 with data retrieval systems that were accessible via web based applications or linked in real time to many users and clients ranking as 5, and hard copy limited reporting systems ranking as 1. Overall Efficiency was ranked 1 -5 based upon the values obtained from the other factors (Data Collection, Data Storage, Analysis and Reporting, and Accessibility) and how well these factors were designed in relation to each other. An integrated system from data entry to data querying without platform changes and or manual steps that cause impedances to the quality and analysis of crash data would rank as 5. The Sum Ranking of the surveyed states was then averaged into a 1-5 ranking schema where 5 demonstrated the overall best practice ranking.

Next, current literature was reviewed, including Transportation Research Board (TRB) reports, reports from leading states, and documentation from the Association of Transportation Safety Information Professionals (ATSIP) annual meetings. Finally the research team identified the components of crash data systems with the best practices and selected the states with comprehensive programs that have these components.

2.3 SURVEY RESULTS

The survey's objective was to determine and rank each state's data collection, storage, analysis and reporting methods with regard to the particular crash-data system's overall accessibility and efficiency. The survey results are shown in Figures 2 and 3. Four states stood out for their technical advances and implementation and for their over all system designs and efficiency. These states are Iowa, Kentucky, Illinois and Massachusetts.

The questions in the survey focused on operating systems, database management systems and support software for analysis and distribution, and the role of those systems in each state's crash-data system. All states surveyed used a Windows NT, 2000 or XP operating system. The dominant database management system was Oracle, which was either an integral part of the design of each new crash-data system or was being migrated from an antiquated mainframe system.

2.3.1 Data Collection

Predictably, survey respondents stressed the need for standardizing data-collection methods and accident forms, and incorporating Global Positioning System (GPS) technology to aid in data accuracy and spatial analysis. Systems such as Traffic and Criminal Software (TraCS) and Model Minimum Uniform Crash Criteria (MMUCC), which will be discussed in following sections, were deemed best practices for collecting and standardizing crash data. The importance of this component was illustrated by Pennsylvania's response, which said that electronic data capture was one of the most advantageous components of its system.

2.3.2 Data Storage

As in all computer systems, storage space and methods are always an area of attention for crash data system users and administrators. From the survey findings, the research team concluded that each state customizes database management systems to meet its needs. The majority of respondents had changed this aspect of their systems within the past five years. The robustness of the Oracle or SQL Server components for querying and exporting data made them a best practice among all the states surveyed. In Montana, the Oracle system helps link DOT traffic and facility information to incident records, allowing for advanced queries and analyses.

2.3.3 Data Analysis and Reporting

The complexity of crash data has been the motivation for developing many customized analytical software packages. All of the survey respondents used a customized analytical system, and 50 percent of the respondents, including New Mexico, California, South Carolina, and Montana, stressed the importance of integrating GIS and GPS into their analytical procedures.

According to the survey results, two factors drive the standardization of crash-data formats and reporting guidelines: the primary end-user's needs for data application and the federal standards of the Federal Highway Administration (FHWA) and the National Highway Traffic Safety Administration (NHTSA).

2.3.4 Accessibility

Data collection, data storage, and analysis and reporting played significant roles in determining the accessibility of a state's crash data. There were many variations of by whom and how the data was accessed. The primary users envisioned in designing data access were the traffic safety engineers. Personnel at Departments of Motor Vehicles (DMVs) and Emergency Management Services (EMS) are also data users although they may access and use the data differently. Massachusetts was identified as a best-practice state owing to its use of the Crash Outcome Data Evaluation System (CODES) that integrated many different data-users into one platform.

2.3.5 Overall Efficiency

Iowa and Kentucky were ranked highest in Overall Efficiency. Both states are able to collect, monitor, analyze and distribute crash data in real time. Reaching this level is a testament to the ability of these states to implement technological advances in data-collection and querying.

The data collected from this survey has been very useful in understanding the broad spectrum of methods and problems related to crash-data systems, and also provided a snapshot of the nations' crash-data systems. However, because the voluntary survey responses to the limited survey questions are widespread, the results of this survey were only able to provide a preliminary exploration of the best practices of transportation departments' crash-data systems. Therefore, the research team further selected four leading states in crash data management for in-depth analysis of their best practices.

2.4 SELECTED STATES BEST PRACTICES

In examining crash-data systems to identify innovative and efficient practices in the four states selected for more in-depth analysis, the research team used the same five system components employed in the survey: data collection, data storage, analysis and reporting, data accessibility, and overall resource efficiency. Each state's system identified as having a best practice in one or more of these areas is described below. The result is a list of the components of an overall ideal system.

The states selected for in-depth analysis were Kentucky, Iowa, Illinois, and Massachu-setts. While none of the four states should be considered to have best practices through-out its system, a component was selected from each state's system as a best practice that should be considered and assessed for the development of the ADOT system.

2.4.1 Data Collection

Data collection is the area where the most states are using technology to improve their crash-data systems. Innovative practices are improving data quality, reducing staff intervention, and expediting data availability within their systems. Of the four selected states, Kentucky, Iowa, and Illinois stand out as leaders in the realm of data collection. Also noteworthy and described below are the MMUCC standards for crash-data collection. While these standards are not considered best practices, they play a very important role in creating an overall model system.

Kentucky uses a custom-developed field system for electronic data entry and collection. Led by the Kentucky State Police, 151 agencies in the state have deployed field units into patrol and response vehicles. The field units are equipped with barcode scanners and GPS units to help auto-populate electronic forms from incidents to violations. The system is live-linked to an enterprise database system that contains vehicle and driver data that is automatically transferred to the electronic form, reducing the time needed for data entry and eliminating data-entry errors. This system employs business rules for data validation that enforce data consistency and serve as a first level QA/QC of the entered data. The GPS system automatically inputs the positional location of the incident, allowing spatial display and query downstream. The system records 90 percent of the MMUCC components for 41 percent of all incident records.

Iowa has developed and utilizes the TraCS field data-collection system. Several states have adopted this system as the national model for collecting incident data. The system is field-deployed with an array of barcode scanners, swipe-card readers, digital cameras, GPS units, and touch pads to facilitate automatic and digital data entry. TraCS utilizes the GPS location of the incident to tie-in roadway facility information automatically in addition to automatically populating data elements from vehicle, driver, emergency, and crime data-bases. TraCS has the additional components of a GIS viewer that helps locate intersections and additional area information, a photo-imaging system to directly attach digital photos to an incident report, and electronic diagramming to sketch incident specifics directly at the scene. This system also has a direct tie-in to Iowa's Computer-Aided Dispatch (CAD) system.

Illinois uses a combination of Iowa's TraCS and a custom-developed, field-based data-entry system. The data-entry system is deployed in vehicles and is equipped with GPS units to determine incident locations. The Illinois system is accompanied by a diagramming tool that electronically details the events with graphic representation. The electronic forms have embedded business rules to ensure data consistency and accuracy in entered data elements. The completed records are transmitted electronically to a centralized data warehouse for retrieval by any authorized user.

MMUCC is a guideline for minimum, standardized data describing motor vehicle crashes and the vehicles, persons, and environments involved. This guideline was created to ensure that officials collected the information necessary to support analysis to improve highway safety at the state and national levels. The first edition of MMUCC was created in 1998; it was revised in 2003 to include new data elements relevant to emerging highway-safety issues such as distracted driving and use of child restraints. State participation is voluntary; however, the data elements are based upon FHWA and other federal criteria.

MMUCC has 111 data elements. Seventy-seven of these elements are to be collected at the scene and include date/time, weather, location, vehicles involved, sequence of events, etc. Ten more elements are derived from the previous elements, and include severity, fatalities, and presence of alcohol. Additional driver information and facility information compose the remaining 24 elements, which are designed to be integrated once the incident is entered into an enterprise database system.

Implementing MMUCC has several benefits to agencies responsible for highway safety. MMUCC improves the quality of state and national incident data by forcing data consistency among agencies and enabling data-sharing and analysis among all participants. A data standard also enables software to be developed and shared across multiple agencies, reducing initial costs for system development.

The three leading states exemplify innovation and efficiency in data collection. While most states are utilizing resources to enter data that was hand-written and later typed, and then entered into an enterprise database system, the three states are saving critical resources for other programs such as mediation and safety analysis. These time-saving approaches are making incident data available in a matter of hours, as opposed to weeks or months. Also incredibly beneficial is that data are entered once and are validated automatically by business and consistency rules. These rules dramatically reduce data-entry errors and improve the overall accuracy of the database.

2.4.2 Data Storage

Data storage is one of the most critical aspects of an efficient system. The development of RDBMS has enabled the seamless storage and retrieval of information to and from almost any application developed within the last several years. The RDBMS database systems reduce the need for manipulating data before transmitting them from system to system, thus saving staff time and resources needed to get information to analysts and decision-makers. All four selected states use an enterprise RDBMS for their data storage systems.

Kentucky utilizes a custom database, Collision Report Analysis for Safer Highways (CRASH), for its incident records. This enterprise system accepts electronically transferred incident records from collection agencies and automatically populates the database tables. CRASH not only holds incident records, but also records for all court cases, citations, and firearm registrations. Relationships established among these different data components could support advanced analysis using different information sources.

Illinois uses a Microsoft SQL Server database for data storage. The database stores data in a central repository for users to access. Several additional systems link to form a one-stop interface for users to access incident and other related information, thus reducing the need to visit multiple locations for data.

Massachusetts employs an Oracle database named CODES. This storage system is part of a national program in which several states participate to help maximize development resources, enforce data consistency, and create data-sharing opportunities. This system uses an enterprising approach that links other databases to form an integrated data solution. EMS, hospital, death, and insurance records are all integrated components of this system.

Iowa uses a combination of Oracle, SQL Server, DB2, and Access databases for its data storage. This system accepts electronic field reports and populates the necessary data elements without user intervention. The system then automatically replicates data elements to other databases for use by other agencies, such as FHWA and municipalities. This system also has a direct integration with the state's citation database.

While all these states have different approaches to data storage, they all have common components that serve as core efficiencies that need to be noted. Significant time is saved by receiving reports and records electronically with minimal user intervention. The linkages to other enterprise systems enable advanced data analysis. Having the data stored in a RDBMS database makes data sharing and transfer to other systems and users efficient and cost-effective.

2.4.3 Data Analysis and Reporting

Data analysis and reporting capabilities vary widely from state to state. Some states are very innovative, connecting their enterprise systems to the World Wide Web to allow 24/7

(24 hours a day, 7 days a week) access, while others choose to allow data access only to desktop users. Some systems can generate custom, ad-hoc reports while others only allow predetermined reporting functionality. The research team has found that most states are using or plan to use GIS in the near future to expand their analytical capabilities. Also detailed in this section is the federally mandated reporting system, Fatality Analysis Reporting System (FARS). FARS itself is not a best practice, however the handling of FARS reporting has implications that could lead to a best practice.

Kentucky's system features a Web portal with GIS functionality. GIS allows Web users to connect directly to the enterprise database system to query locations for analyses, including high-accident locations and alcohol-related incidents. The system allows the retrieval of individual incident reports or custom summarized reports for data elements. Extracting data is a core function that allows users to bring raw data into their own systems for further analysis. A user can also use the online statistical analysis package to analyze data directly from the open portal.

The Iowa Department of Transportation has created a custom desktop interface to link users to its wide array of system databases. The interface contains limited GIS mapping of incidents and a data-export module to help users bring incident reports into their own applications for further analysis. Iowa's system comes with advanced statistical analysis and charting capabilities as well as a portal to Intersection Magic for diagramming of incidents at specific intersections.

Illinois utilizes a heavy GIS component in its analysis and reporting. The GIS component allows for general mapping and visualization of incidents. Custom reports can be generated with graphical components embedded. The GIS integrates facility and infrastructure data such as roads, bridges, and railroads into the analytical capabilities. Illinois also maintains Internet access to summarized quarterly reports for download.

In evaluating data analysis and reporting best practices, it is worth considering the Fatality Analysis Reporting System (FARS). In 1975 the USDOT and NHSTA designed and developed a reporting system for fatal accidents to assist the traffic safety community in identifying problem areas. FARS maintains fatality data for all fifty states including Puerto Rico and the District of Columbia. States are required to submit fatality information to the system within 30 days of the fatality. Fatality information is then made avail-able on an annual basis to Federal, state, and local municipalities as well as private groups and research organizations. The system records 100 data elements that are derived from accident, vehicle, driver, and person reports. Each element is standardized and entered on custom FARS report forms for submission to the national system. Some progressive states are including in their FAR report forms plans for automatic FARS reporting to eliminate some of the paperwork involved in meeting the FARS requirements.

Among the innovations in analysis and reporting that add value to a user's daily workflow, GIS provides a good graphical component that helps users visualize trends that might not be apparent in a simple tabular format. GIS also allows users to query information at varying levels of geography as opposed to the traditional intersection or area query. The ability to generate custom reports reduces the need for data export, ensuring that the user is analyzing the most current information available. The usage of centralized statistical analysis and charting tools help enforce data consistency across an organization in outputs as well as using the most current data available.

2.4.4 Accessibility

While all the aforementioned systems and technological innovations can dramatically increase an organization's efficiency, the time and resources that are recovered can quickly disappear if users do not have adequate access to the tools and data. Waiting for exported data or specialized software installations can be time-consuming and costly. This has directed the most progressive states toward Internet/intranet solutions that run within stable Internet browsers such as Internet Explorer and Netscape.

Kentucky is the leader in data and tool accessibility. Its Web-based system allows users 24/7 access to its information resources. The Web solution enables GIS mapping, summarized database query and export, and individual incident-report lookup. Over 120 agencies within the state and FHWA have direct access to these tools, including 90 predefined management and statistical reports.

Iowa also has a progressive accessibility innovation, but it does require users to have licensed GIS software to fully utilize the capabilities. The GIS allows users direct access to the enterprise system from their desktops for data export, spatial query, and mapping. The Iowa system's custom interface allows all users access to the custom analytical tools and database queries directly from their desktops.

2.4.5 Overall Efficiency

One of the driving objectives for an improved crash management system for ADOT is to improve the overall efficiency of its practices to collect, store, maintain, and analyze crash data. Improving efficiency will reduce the demand for resources and allow the state to direct the funds toward other important safety-related activities. Kentucky and Iowa exemplify optimal operation efficiency.

Through the utilization of its systems, Kentucky has eliminated its entire backlog of incident reports. Its databases are now day-current through the utilization of electronic data entry and electronic data transfer for reports that are entered by hand in the office. By using a single, shared repository for data storage and a Web-deployed interface for minimize staff involvement in the data-entry process and ensure data consistency for end-users. The Web portal also gives managers and analysts quick and seamless access to the necessary resources to achieve decreased response time for critical safety issues.

Iowa's TraCS system maximizes readily available data in the data-collection stage, reducing data-entry time and duplicate data entry. The associated business rules mitigate the need for additional staff intervention to validate and do quality control on incident records. Automatic electronic data-transfer processes distribute incident records to all necessary agencies, eliminating the need for end-users to export data from the enterprise system for

Table 1. System Design Recommendations

Best Practice Components	System Design Recommendations
Data collection	Electronic data entry
	Field-based data entry
	Domains for validation
	Business attribute rules
	Automatic data collection from swipe cards/bar code readers
	GPS locator
	GIS field display for locating
	Automatic element entry from remote databases
	Data collection standards (MMUCC)
Data storage	Utilize RDBMS
	Additional enterprise database integration
Analysis and Reporting	Generate custom ad-hoc reports
	Custom data queries
	Data export to multiple formats
	User friendly GIS capabilities
	Insert GIS graphics into reports
	Access to previously generated reports
	Advanced statistical analysis
	Chart and graph capabilities
	Links for additional databases for advanced analysis
Accessibility	Centralized web application
	One-stop portal for all information
	All information is live linked to enterprise data
	Password security

analysis and reporting. The desktop interface puts custom tools and reporting capabilities at managers' and analysts' fingertips.

The use of electronic, field-deployed data entry and electronic data transfer are dramatically reducing staff involvement in the data-collection process. Enterprise database systems are providing quick and seamless data access to those who need the information. Specialized tools on the desktop, or the Internet, are providing managers and analysts quick access to tools and to reports that used to take significant amounts of time to generate.

2.5 IDEAL SYSTEM COMPONENTS

The five areas highlighted in this report – data collections, data storage, analysis and reporting, accessibility, and overall efficiency – constitute the necessary system components for a comprehensive crash-data system (Table 1). The ideal crash-data system will incorporate the best practices identified for each area, improving system performance, increasing efficiency, and minimizing critical resources.

The system starts with data collection. States like Kentucky and Iowa have proven that electronic, field-based data entry and electronic data transfer can expedite data entry and increase efficiency by reducing staff involvement in these processes. This also increases data consistency and accuracy though the use of data element standards and business rules for data validation and QA/QC. The use of an open RDBMS for data storage allows great flexibility in data accessibility and analysis. The integration of outside databases is also very beneficial. Direct links to systems such as facility, average statistics, citation, driver, and vehicle databases prove to be positive. The ideal configuration of analysis and reporting components varies with needs, but a few specific functions and capabilities should be targeted. The ability to generate custom reports and queries from a centralized location seems to provide optimal efficiency for end-users and managers. User-friendly GIS capabilities should be included to perform mapping and analysis with integration into reports to add a graphical component. A system should include access to previously generated reports for easy access and download. The ability to perform advanced statistical analysis and charting by pulling data directly from the enterprise database, ensures the most current information is being used. For accessibility, it is apparent that a Web-based application for data retrieval and analysis provides the most access to the most users.

2.6 BEST PRACTICES CONCLUSION

Several states have created efficient and innovative practices to handle crash data. Most efficiency has been gained through automation of frequent processes and minimizing or streamlining data-collection efforts. The less staff intervention, the less time and resources are spent to get the data to analysts and decision-makers. Enterprise databases and common access points increase data accuracy and overall utilization of these systems, leading to safer transportation systems. While the initial cost of these systems and integrations can be high, the return on investment can be quickly realized as staff interaction decreases. The savings can result in cost-cut through reduced need to hire additional staff or redirection of valuable staff time for other safety-related activities.

Table 2. Interview Participants

Organization	Department/Group/Section
ADOT	Hazard Elimination Safety
	Risk Management
	Traffic Records
	Transportation GIS
	TPD
	ATRC
City of Mesa	Traffic Studies
City of Phoenix	Street Transportation
City of Glendale	Information Systems
City of Tempe	Transportation
Maricopa Association of Governments	Transportation Department
Pima Association of Governments	
University of Arizona	
Arizona Dept. of Public Safety	
Arizona Tribal Council	
FHWA	ITS
	Engineering Development
	Planning
	Safety

3. USE CASE

In order to create a strategy for ADOT to move its systems into a best practice level for analyzing crash data, its current systems and environment must be defined. A use case study was designed to analyze ADOT's current desires, assets and capabilities, and workflows. This section highlights the methods and results from the use case study, which feeds into the gap analysis along with the results from the best practices study.

3.1 INTRODUCTION

A use case study is a multi-level research project that identifies the current desires, assets and capabilities, and workflows for a particular organization. This kind of study delves into the specifics of an organization, resulting in a broad and complete understanding of its business practices. A use case study can be composed of interviews, surveys, document reviews, and data analysis.

For ADOT's crash data collection and analysis system study, a combination of interviews and data analysis was used to define ADOT's current assets and capabilities. The research team visited ADOT's facilities and conducted interviews with several key players responsible for crash data, and also interviewed personnel of external entities such as the Federal Highway Administration (FHWA), regional governments, and local municipalities. Some additional interviews were conducted over the phone and through email. ADOT's existing data was also reviewed.

Three areas were identified as critical for appropriately defining ADOT's business practices: Internal Desires, Existing Assets and Capabilities, and Workflows. This report has a section on each. The Internal Desires section identifies the current desires expressed by the various users of ADOT's systems and data. These desires fall into the five best practices groups of Data Collection, Data Storage, Analysis and Reporting, Accessibility, and Overall Efficiency. The section of Existing Assets and Capabilities highlights ADOT's current systems, databases, GIS capabilities, analytical tools, reporting tools, and data sharing. The Workflow section identifies data collection components and data flow from organization to organization.

Once all of ADOT's current assets and workflows were identified and its staff's desires defined, a comparison could be made between ADOT's current systems and the ideal system components from the best practices survey. This comparison is called a Gap Analysis, and the results from this analysis are included in this report.

3.2 METHODOLOGY

To facilitate the use case study, the research team conducted a series of on-site interviews to identify needed information. These interviews provided the team with detailed descriptions of the desires, systems, and assets currently in place among Arizona's crash data stakeholders. It was not feasible to interview all stakeholders throughout the state, so representative groups were selected. The groups of people that the research team interviewed are shown in Table 2.

Table 3. User Desires

System Components	ADOT User Desires
Data Collection	Paperless incident submission
	Road open dates
	Automatic QA/QC procedures
	Street naming conventions
	Collect signalized intersections
	Crash definition standards
	Collect 1st, 2nd, and most harmful events
	X,Y for all incidents
Data Storage	Link State Highway System Log and ALISS
	Digital storage and retrieval of incident reports
	Ability to change ALISS
	ALISS documentation
	Data sharing between local, regional, and state governments
Analysis and Reporting	Prioritized accident locations
	High risk/hazard locations
	Safety improvement effectiveness
	Accident and severity rates
	Automatic FHWA reporting
	GIS database of safety improvements
	Intersection Magic integration
	Auto format data query
Accessibility	Municipal and Regional data access
Overall Efficiency	Change management procedures
	Data one-stop

Some people and groups could not attend the on-site interviews and were contacted via phone and e-mail. In some cases, follow-up information was needed from people interviewed in person, and these individuals were contacted via phone or e-mail to acquire more detailed information. While this report was meant to be inclusive, not all groups were interviewed and, therefore, this report may be lacking certain desires, assets, and capabilities.

The interviewees identified several data sources, applications, and reports as critical to the business practices of ADOT and the various other organizations. These components were investigated through independent research techniques that varied depending on the type of source material available. GIS data was evaluated using ESRI software. Reports were reviewed by obtaining samples, and software packages were researched on-line and through contacting the developers.

3.3 USE CASE RESULTS

The following subsections describe the findings on the three categories: Internal Desires, Existing Assets and Capabilities, and Workflows.

3.3.1 Internal Desires

This section of the report contains the desires expressed by various interviewees. Some of these desires are general ideas to improve system efficiency while others are specific to a particular analysis or business process. During the interview process, participants were given opportunities to tell the research team what would make their daily workflows easier and what items they desired to have to help with their works but currently did not have. These expressed desires are listed in Table 3. To make these desires fit into the context of the gap analysis, the team have grouped them into the five categories identified previously in the best practice survey: Data Collection, Data Storage, Analysis and Reporting, Accessibility, and Overall Efficiency. Each of the desires is presented in the following.

3.3.1.1 Data Collection

<u>Paperless Incident Submission.</u> Great efficiencies could be made by eliminating the need for incident reports to be typed/entered by both the incident officers and ADOT personnel. Currently, all records are submitted in hard copy to ADOT and hand entered into the Accident Location Identification Surveillance System (ALISS).

<u>Road Open Dates.</u> There is a desire to know when a road segment is opened for traffic. There needs to be a way to indicate whether an accident occurs prior to a road's being open or after.

<u>Automatic QA/QC procedures for data entry.</u> There needs to be greater quality assurance/quality control for improved data accuracy. The use of domains and the integration of additional outside databases would help this initiative. The City of Tempe estimated that 10 percent of records have a minor data entry problem.

Street naming conventions. There is a desire for street naming conventions to be used throughout the database. If a municipality changes the name of a street and it becomes official, the database should reflect the change.

Signalized intersection database. An inventory of signalized intersections should be included in the facility database and linked to the ALISS.

Crash definition standards. There needs to be an agreement within the highway safety community on exactly what constitutes a particular kind of crash. Currently, end-users sometimes need to alter the crash type to run accurate analysis.

Collection of data on harmful events. Field officers currently collect these data elements. Harmful events are "value-added" upon data entry into the ALISS. The practice should be expanded to incorporate up to six events.

X,Y coordinates for all incidents. Approximately 80 percent of all incidents have approximate X,Y coordinates. There is a desire for 100 percent and high accuracy because the positional location of the incident determines if it is an intersection accident or is along a particular route.

3.3.1.2 Data Storage

Linkage between ALISS and State Highway System Log. The interview with FHWA highlighted this very critical need. The data from ALISS and the State Highway System Log are not easily linked for analysis. These two systems need to be linked to determine accident rates by facility type.

More efficient storage and retrieval of original incident reports. Currently, incident reports are stored on microfilm and require manual retrieval, printing, and mailing. Users desire access to the original report to help analyze a specific incident or QA/QC the database. On-line or digital access to these reports would save time and effort in obtaining these reports.

Ability to change ALISS data fields and data entry form. The current ALISS database and data entry form are not customizable. If a new data element needs to be collected in the future, the current system cannot be altered to accommodate this.

Current ALISS documentation. No documentation on the system and data fields were provided when ALISS was delivered, making it extremely difficult to maintain and describe the system. Metadata is required.

Data sharing between ADOT, regional, and local governments. Some municipalities correct or update incident records, but do not submit the corrected or updated records back to ADOT for revising its database. In addition, facility information is updated at the local level but only occasionally passed to ADOT.

3.3.1.3 Analysis and Reporting

Ability to determine prioritized accident locations. There is a desire to identify the most frequent incident locations (i.e., top 10) for a user-defined geographic area and user-chosen criteria (e.g., vehicle type, pedestrian, etc.). Interviewees also said that it would be beneficial to be able to identify locations that had high priority for improvement for a user-defined geographic area. Several groups mentioned that they do this on a regular basis for their jurisdiction, but it is largely a manual analysis.

Identify high risk/high hazard locations. The ability to identify locations of high risk to pedestrians, buses, passenger trains, and cars would be very useful. The ability to examine railroad crossing condition, rail speed and volume along with car speed and volume could identify higher-risk locations for cars near rail lines. High risk and hazard locations could also include exposure to buses, pedestrians, and hazmat vehicles.

Safety improvement program effectiveness analysis and accident reduction rate analysis. The capability to analyze improvement programs to evaluate effectiveness for the program is necessary. This would require historical crash data for a location, data for improvement programs (dollars spent, location, improvement), and crash data after improvement. This would answer the question, “Did the improvement work and how well?”

Accident and severity rates. It is critical to determine accident/crash rates for road segments and intersections by road type. A disconnect between accidents and facility information prevents this analysis. Also important are the severity rates for accidents. It would be very beneficial to be able to compare crash and severity rates for selected road segments with Arizona statewide and the national averages for a particular facility type. It was also noted that the ability to change the length of a road segment into a “corridor” for crash and severity rate analysis would be useful.

Automatic FHWA reporting. Efficiencies could be improved by automating the reporting of data to FHWA.

ALISS reports in digital format. Currently the reports coming out of ALISS are SQL printouts and not electronic copy. There is a desire to make electronic copy of these reports by using exporting data into MS Excel spreadsheets.

GIS inventory of safety improvements. The ability to consider safety improvements such as barrels, bumpers, and guardrails in analysis would be beneficial.

Intersection Magic integration. Many municipalities use Intersection Magic to help visualize and analyze incident information. Efficiencies could be achieved by minimizing data formatting.

Auto-format data query. Several analytical systems are in use in Arizona, and each needs data to be in a certain format. The ability to generate custom formats for data export would be very beneficial.

3.3.1.4 Accessibility

Municipal/regional government data access. Currently, local government agencies contact ADOT to request incident information for their jurisdictions. These data are queried from the ALISS system and mailed to the local agencies. The efficiency of this process could be greatly increased by providing local government agencies on-line access to the ALISS database to download the crash data for their jurisdictions.

3.3.1.5 Overall Efficiency

Change management for altered data standards. All departments and agencies desire better communication so they can share and discuss changes made to the various systems. The example of changing the abbreviation "Av" to "Ave" can cause systems and analysis tools not work properly.

Decision support one-stop. There is an expressed desire for one-stop access to data. The ability to go to one source for all data needs would minimize data collection efforts and improve response times.

3.3.2 Existing Assets and Capabilities

This section highlights the existing assets and capabilities of the crash data community within Arizona. Systems, databases, analyses, and reporting capabilities are described to set the baseline for the gap analysis in the following sections of this report. While this section is meant to be inclusive of all existing assets, there undoubtedly are assets that were not brought to the attention of the research team. The known existing assets are described below.

ALISS is the central repository for crash data within Arizona. This is a Microsoft SQL Server database with Visual Basic forms for data entry. All incidents involving an injury or causing a minimum of $1,000 in property damage are reported to this database for record. Accidents within the jurisdictions of military bases or Indian reservations are not required to be reported, though on occasion some are. Incident records are submitted to ADOT Traffic Records Section for inclusion into the database and are entered by hand into the system by the 12 members of the Traffic Records staff. The data entry system has some domains, or lookup tables, to assist in the data entry process, and there is geocoding functionality in which the system automatically locates approximately 80 percent of all records. Most data elements stored in ALISS are included on the Arizona standardized accident form. The elements not on the form, such as most harmful event, are "value-added" by Traffic Records Section staff at the time of data entry. The ALISS database has over 115 stored reports that generate hardcopy outputs directly from the database. These reports can have customized parameters set to limit or query certain data elements within the database. These reports are stored within SQL and can be generated by contacting the Traffic Records Section. The ALISS database has export functionality to deliver data to local, regional, and national agencies. Queries can be run to extract information based upon area and are delivered to agencies as comma-delimited text files.

The State Highway System Log stores highway facility information. Data elements include number of lanes, shoulder width, speed limits, lane width, and pavement type.

Intelligent Transportation Systems (ITS) apply technology based solutions such as advanced sensors, computers, electronics, and communications technologies, to transportation management to improve the overall safety and efficiency of multimodal transportation systems. ADOT's ITS has several systems and databases providing data to the public on a real-time basis. Weather information, highway restrictions and closures, current traffic speeds, ramp metering, live video feeds, and current accident locations are all components of this system. The Highway Conditions and Reporting System (HCRS), Road Weather Information System (RWIS), Freeway Management System (FMS), Variable-Message Signs (VMS), Traffic-Interchange Signal (TIS), and Closed-Circuit Television (CCT) are all systems utilized by ITS.

The Highway Conditions Reporting System (HCRS) maintains information on highway closures, conditions, and maintenance.

The Road Weather Information System (RWIS) monitors pavement and atmospheric sensors, then processes this information for display within the ITS system.

Intersection Magic is an “out of the box” application designed by Pd’ Programming, Inc. This application graphically displays various incidents and some of their attributes at a single intersection. This application is licensed and utilized by several municipalities throughout the state. Data are exported out of ALISS or out of local databases, then manipulated and read by Intersection Magic for display.

The Maricopa Association of Governments (MAG) GIS database serves as a warehouse for various transportation-related GIS datasets. GIS layers include roads, traffic flows, and signals within MAG’s jurisdiction. These data are updated frequently and are adjusted by working with local municipalities. MAG utilizes EMME-2 software for modeling multi-modal traffic planning networks. It utilizes matrix manipulation and other tools to distribute and forecast traffic over an urban or regional area. Traffic forecast periods are usually up to 25 years. As is typical of most traffic planning software, EMME-2 users can alter the analysis portion of the program by changing the matrices, inputting assignment procedures, or using interactive calculators for evaluation and impact analysis. Crash data can be one of the add-ons to the program. If statewide averages/rates are generated for facility types, then crash rates can be predicted for various future-year scenarios to complement the traffic forecasts.

The Traffic Records Microfilm Inventory maintains all reported incident forms on microfilm. These original records are submitted to ADOT from various agencies within the state. Each record has a unique identifier that correlates the microfilm record with the record in the ALISS. Microfilm incident reports can be reproduced in a hardcopy format for additional incident record information. Upon request, the original incident report can be printed and mailed to end-users for in-depth analysis.

The ADOT GIS database is currently being migrated from an ArcInfo database to a GeoDatabase with dynamic segmentation and linear referencing. The database will soon sit on a Microsoft SQL server running ArcSDE to serve desktop clients. Also under development is an ArcIMS Website to allow Internet access to the database. The GIS database contains information on roadways, intersections, traffic flow directions, and other facility information in addition to base map information. ADOT's GIS has several analytical functions. An ArcIMS Website would allow users to build custom maps from the Arizona Transportation Information System (ATIS) library. The ArcView 3.x extension program allows users with ArcView 3.x to view and analyze geospatial information, including facility information. There is functionality to geocode information from the ALISS database, a GPS tool for collecting information, and tools for integrating bridge and railroad crossings. The GIS is based upon linear referencing technology and therefore allows for incident analysis along a route not just at an intersection.

ADOT's Data Warehouse is a data storage and retrieval system designed to be a one-stop location for data access. The warehouse has a query wizard at its front end for data retrieval and export. The Data Transformation Services (DTS) software running on top of the database perform cleansing routines, geocoding, and data validation to help load and export data. Currently, the system is accessible on the ADOT intranet, and all information has the geographic component of a route/milepost. The ADOT Data Warehouse has built- in query and export functions to help end-users acquire safety related data. Route and milepost can be used to define areas for data queries as well as custom-data-element queries. The returned data can then be exported in tabular format for use in analysis. There are 50-60 stored queries to expedite the data retrieval process.

Several municipalities' traffic safety departments maintain and use local databases to store their own incident records. Some choose to enter incident records into their local databases and then send the incident report to ADOT, while others wait for ADOT to process the incident report to enter incident records, request the records, and then populate their databases with the ADOT records. These databases are often updated by correcting data entry errors in the ADOT record and are therefore potentially more accurate. Local municipalities have reporting capabilities to generate reports for pedestrian, bicycle, and fatal incidents. They also have analytical capabilities to determine the top 10 high-risk locations for incidents by types such as angles, striping, and visibility. Some municipalities have the ability to geocode their incident data by utilizing GIS software. Some local municipalities have automated tools for formatting data from ADOT to support their analysis routines. Several groups that use Intersection Magic have automated their data from ADOT into the Intersection Magic format to reduce data processing time prior to analysis. Others run ADOT's data through routines that geocode incidents, allowing GIS systems to read these data for advanced analysis using geography.

The Traffic Accident Data System (TADS) is a system being developed by the City of Phoenix Police Department that utilizes field-based data collection and entry for incident reports. These reports are electronically transferred into the police database and made available for analysis instantaneously. Soon these records will be submitted electronically to ADOT's ALISS.

The State Maintained Streets Photo Log is available for all to use. This log has captured photos from along all state maintained streets within Arizona.

3.3.3 Workflows

There are several different workflows or dataflows within the crash data community in Arizona. Each of these workflows is highlighted in Figure 4 to show general movement of data throughout the community. Each community is different, but each will typically follow one of these models in getting data to and from the ADOT ALISS.

In smaller municipalities across Arizona, the police department collects information using a hand-written, field-based form. This form is then photocopied and sent to ADOT for entry into ALISS. ADOT receives the form and hand-enters the data elements. On a periodic basis, the municipality requests the data and an export file is generated and sent to the safety or traffic engineering department of the municipality. The municipality then manipulates the file format, performs a QA/QC check, and analyzes the data. Some progressive municipalities store the data in a database for future use once they receive the file from ADOT. On occasion, the municipality will notify ADOT of errors in the data for correction in ALISS, though this is not common.

In medium and large municipalities, the common system is for the police department to collect incident information using a hand-written, field-based form. The form is taken to the office, where the data is hand-entered into the municipality's incident database. An incident report is generated, printed, and mailed to ADOT for hand entry into ALISS. Most municipalities that use this workflow do not request the data back from ADOT, as they already have the information in their own systems. The traffic engineering or safety department then requests the data from the incident database and formats the data as necessary for its analyses.

The City of Phoenix police collect incident data via a field-based data-collection system that transmits data directly to the police department's database. Soon this database will electronically submit the accident report directly to ALISS. Once the data is in ALISS, the city requests that the relevant data be sent to the appropriate city personnel, where the data are entered into their system and formatted for analysis.

Once a record has reached ALISS, queries are run to distribute data to various other agencies upon request. Groups such as MAG, PAG, and internal ADOT groups request this data for their analyses. Each group must format the data for use in its own analysis systems. ALISS also generates reports for groups such as FHWA and the Fatality Analysis Reporting System (FARS). Frequently, the ALISS data is sent to ADOT's Data Warehouse for query by those who have access to ADOT's intranet.

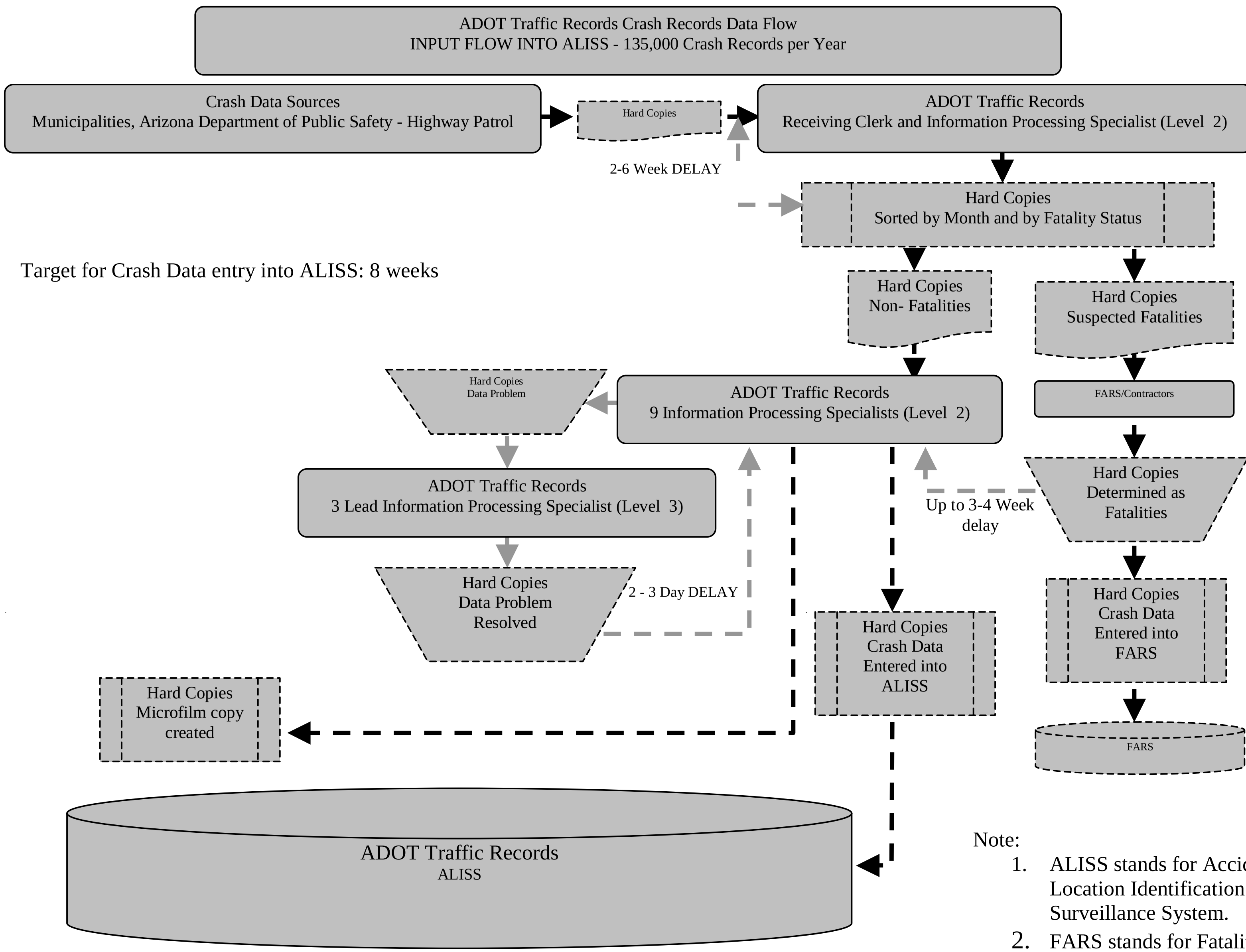

Figure 4. Crash Records Data Flow

Note:
1. ALISS stands for Accident Location Identification Surveillance System.
2. FARS stands for Fatality Analysis Reporting System

4. GAP ANALYSIS

This section of the report is a comparison between the ideal system components from the best practices report and the existing capabilities and assets from the use case study. The gap analysis highlights the deficiencies of the current system and outlines the steps needed to bridge the gaps between existing and proposed systems. It feeds into the third and final part of the study, the technical memorandum.

4.1 INTRODUCTION

The best practices report is broken down into five sections: Data Collection, Data Storage, Analysis and Reporting, Accessibility, and Overall Efficiency. The ideal system components are taken directly from these sections and will serve as the goals for ADOT to aspire to in developing its systems. The gap analysis below compares these ideal components with capabilities and assets already in place within the crash data community. These assets and capabilities were previously defined within the use case study. The outputs from the comparison result in the gap analysis, which then feeds into the technical memorandum.

The internal desires section of the use case is also a portion of the gap analysis. These desires serve as additional goals for Arizona’s crash data community, whether the desire is expressed as a best practice or not. Internal desires detailed in previous sections of this document will not be repeated in the gap analysis unless the desire is particular to a specific ideal system component. All identified desires are in the technical memorandum, however.

4.2 METHODOLOGY

To identify all the components necessary for the gap analysis, a best practice report and a use case study were conducted. The best practice report began with an on-line survey to identify the states that utilized technology to achieve the best practices in data collection, data storage, analysis and reporting, accessibility, and overall efficiency. This survey identified the states of Kentucky, Iowa, Massachusetts, and Illinois as having best practices in at least one of these areas. These states were then examined for specific aspects that improved user efficiency. The most efficient practices were used to define the ideal components for a crash data system and were fed into the gap analysis as a target for ADOT to aspire to. The use case consisted of a series of interviews with many of the stakeholders within Arizona’s crash data community. The use case interviews focused on internal user desires, existing assets, existing capabilities, and workflows. Aspects of each section were defined for each group and passed to the gap analysis

Once all the necessary information was gathered, a comparison was undertaken to highlight system deficiencies. These deficiencies in combination with the expressed desires not encompassed by the ideal system components are the output for the gap analysis and serve as specific goals for the crash data community within Arizona.

Best Practice Component	System Design Recommendation	Recommendation Benefits					
		Reduce Staff Intervention	Improve Analysis Capabilities	Improve Efficiency	More Accurate Data	Timely Management Decisions	Improve Reporting Capabilities
Data Collection	Electronic data entry	◆		◆	◆		
	Field-based data entry	◆		◆	◆		
	Domains and business attributes for validation	◆		◆	◆		
	Automatic data collection from swipe cards/bar code readers	◆		◆	◆		
	GPS/GIS for incident locating	◆	◆	◆	◆	◆	◆
	Data collection standards		◆		◆		
	Automatic data entry from remote databases	◆		◆	◆		
Data Storage	Use RDBMS	◆	◆	◆	◆	◆	◆
	Additional enterprise database integration	◆	◆	◆		◆	◆
Analysis and Reporting	Custom reports and queries for export	◆	◆	◆		◆	◆
	Multiple format and customizable data export	◆		◆			◆
	User friendly GIS	◆	◆	◆		◆	◆
	Advanced statistics, charting and graphing		◆	◆		◆	◆
	Access to previously generated reports	◆		◆		◆	◆
	Links to additional data resources for advanced analysis	◆	◆	◆		◆	◆
Accessibility	Centralized web application that is live linked to enterprise data	◆	◆	◆	◆	◆	◆
	One-stop portal for all information	◆	◆	◆	◆	◆	◆
	Password security	◆	◆	◆			

Figure 5. Best Practice Benefits

4.3 BEST PRACTICE RESULTS

The five areas highlighted in the best practices report—data collection, data storage, analysis and reporting, accessibility, and overall efficiency— define the ideal system components for a comprehensive crash-data system. The ideal crash-data system incorporates the best practices to improve system performance, increase efficiency, and minimizes critical resources (Figure 5).

Based upon these factors, the system starts with data collection. States like Kentucky and Iowa have proven that electronic, field-based data entry and electronic data transfer can expedite data entry and increase efficiency by reducing staff involvement in these processes. This also increases data consistency and accuracy through the use of data element standards and business rules for validation and QA/QC.

The next system component comes from the data storage realm. The use of an open RDBMS allows for great flexibility in data accessibility and analysis. The integration of outside databases is also very beneficial. Direct links to systems such as facility, average statistics, citation, driver, and vehicle databases prove to be beneficial.

The ideal configuration of analysis and reporting components varies with desires, but a few specific functions and capabilities should be targeted. The ability to generate custom reports and queries from a centralized location seems to provide optimal efficiency for end-users and managers. User-friendly GIS capabilities should be included to perform mapping and analysis with integration into reports to add a graphical component.

A system should include access to previously generated reports. The ability to perform advanced statistical analysis and charting using data directly from the enterprise database ensures that the most current information is being used.

For accessibility, it is apparent that a Web-based application for data retrieval and analysis provides the greatest access to the most users.

4.4 USE CASE RESULTS

The areas of focus for the use case study – existing assets and capabilities, and workflows – define the current operating environment for the crash data community in Arizona. Systems and databases are defined and analysis and reporting capabilities are identified, giving an overall picture of crash data collection and analysis.

Although the City of Phoenix Police Department is experimenting with electronic collection of field data to help efficiency Arizona mainly uses hand-written field reports for data collection of incidents. These hand-written reports are then either entered into local databases or passed directly to ADOT for entry into ALISS. In the event that the local municipality enters the data into a local system, the report is still passed to ADOT's ALISS as a hardcopy printout. ADOT staff manually enter all incident records into ALISS for storage. The incident records are geocoded to a location and certain data elements are "value-added." The hard copy is then copied to microfilm for storage. Incident records are exported from the database and sent to an agency when it requests them. Most agencies reformat ALISS export data to make it acceptable for analytical software such as a GIS and Intersection Magic. Stored queries and reports generate frequently utilized analyses and summaries of incidents in hard copy. The ALISS database is routinely updated in the ADOT Data Warehouse for query and is downloaded through ADOT's intranet. The Data Warehouse stores a variety of transportation-related data, including facility information, and it provides customizable queries to users for data download. The ADOT GIS Section provides access to GIS data, allowing users to visually represent incident records for spatial analysis.

4.5 COMPARISON

The ideal system components are compared with the use case components to identify gaps in Arizona's crash data systems. The comparison is organized by the five system components: data collection, data storage, analysis and reporting, accessibility, and overall efficiency. Each component is briefly discussed in the following. The overall output is highlighted in the last section of this report.

4.5.1 Data Collection

The best practice in data collection utilizes field-based electronic data entry with a handheld unit or a laptop computer. The incident form contains domains and business attribute rules for data validation QA/QC. The form utilizes automatic data entry from vehicle and driver's license databases as well as global positioning system (GPS) for GIS locating. The incident form also conforms to MMUCC data element standards. The electronic incident forms are automatically transferred to the central repository, and the database is updated without user intervention (Table 4).

Table 4. Current Practices – Data Collection

Best Practice	ADOT Current Practice
Field-based electronic data collection (laptop or Personal Digital Assistant (PDA))	Phoenix only. Rest of state uses paper data collection
Business attribute rules and domains for QA/QC	Some domains and business rules
Automatic data entry from external database (D.L., vehicle)	None
GIS or GPS locating in field unit	None
MMUCC standards	Essentially compliant
Electronic data transfer of incident records	None

Arizona's crash data community is beginning to explore some of these system components, but none has been universally adopted. The City of Phoenix is beginning to use field-based, electronic data entry, but the rest of the state is using hard-copy incident reports that are sent to the central repository. ALISS does employ domains and business attribute rules to help data validation and consistency, and these rules can be expanded to automate data entry routines. GIS and GPS positional attributes are not entered into the report until the report is received at ADOT. Data collection routines do not currently use vehicle registration, driver's license and other outside databases to help the data entry process. Arizona does conform to several Model Minimum Uniform Crash Criteria (MMUCC) data-element standards.

4.5.2 Data Storage

The best practice in data storage uses Relational Database Management Systems (RDBMS). RDBMS has the core functionality of linking to other enterprise databases, allowing users to explore and analyze data not contained within the primary database. These databases can include driver's licenses, vehicle registrations, crime records, transportation facilities, weather, traffic counts, statewide averages, and so on (Table 5).

Arizona utilizes a RDBMS to store incident records. Arizona also maintains several other enterprise databases, but none is actively linked to ALISS. The ATIS system is a very good start in relating additional information, but it does not include incident records.

Table 5. Current Practices – Data Storage

Best Practice	ADOT Current Practice
Utilize RDBMS	Utilize RDBMS
Link or Relate Other Enterprise Databases	None

4.5.3 Analysis and Reporting

Best practices in analysis and reporting allow users live access to the central repository for incident reports. Such access allows the generation of custom ad-hoc or previously generated reports. Users have access to custom data queries with the ability to export these selected data in several different formats. More advanced systems allow the user to define the fields and formatting of the data export for direct integration into analytical and chart/graphing software packages. These systems employ user-friendly GIS capabilities and the ability to export GIS graphics and analysis results into reports for visualization. Advanced statistical analysis is available as well as external data from related databases (Table 6).

Arizona has several of these analysis and reporting components, but most are not quite best practices. Users have access to custom and stored reports from the ALISS by requesting hard copies from the Traffic Records Section at ADOT. Users can also receive custom data queries in multiple formats through the same request system. However, users can only manipulate the format of the output once the data is sent to them. The system does not contain the functionality to specify the formatting of the data structure on export. Users do not have access to the live database, only to data that has been exported by request or through the ADOT intranet to the data warehouse. ADOT does provide advanced GIS capabilities to users with ArcView 3.x software through the distribution of the ATIS library. Users without GIS software do not have access to any GIS function. Users must rely on their own software for advanced statistical, charting, and graphing functions. Data within the data warehouse do have common linking elements of route and milepost to serve as an ad-hoc relation amongst databases. However, these databases are not completely related, thus requiring additional user intervention to analyze data together.

Table 6. Current Practices – Analysis and Reporting

Best Practice	ADOT Current Practice
Live access to central repository for incident records	None
Custom ad-hoc reports or access to Previously generated reports	Can be requested from Traffic Records
Custom data queries	Can be requested from Traffic Records
Export data in multiple formats	Can be requested from Traffic Records
User defined export formatting	None
User-friendly GIS for analysis and reporting	User-friendly GIS, however ALISS is not GIS Friendly
Advanced charting, graphing and statistical analysis	Users must rely on their own software packages
Access to external data sources	Access is available via the Data Warehouse

4.5.4 Accessibility

The Best Practice for data accessibility is a one-stop portal for information. This can be very difficult to achieve, given the magnitude of transportation information available and needed throughout the community, but recent innovations in Web technology have accomplished this task. Centralized Web-based applications are providing users the ability to perform all the best practices analysis and reporting functions from one spot. Web applications typically are accessible 24/7 and have password security to prevent unauthorized access to sensitive information. Information and data sources are live-linked to databases and warehouses, allowing users to access the most up-to-date information (Table 7).

Arizona users have access to data resources, but most resources require staff to query the database, export the required data, and send the data to the end users. There are automated data-access tools associated with the data warehouse, but the crash data is not live-linked to the warehouse and users only have access if they can get to the ADOT intranet. The data warehouse is designed to be a one-stop portal to transportation data, and it does a good job of storing and retrieving data. Unfortunately, the warehouse is only available to ADOT users. The only centralized Web application is for real-time traffic information through the ITS system, and this system does not include incident or facility information.

Table 7. Current Practices - Accessibility

Best Practice	ADOT Current Practice
One-Stop portal for information	Data warehouse provides access to ADOT users
Centralized Web-based application	None
Security for sensitive information	Sensitive information not available
Access to live data and databases	None

4.5.5 Overall Efficiency

The key best practice for overall efficiency involves automation and reduction of staff involvement in day-to-day operations. Items like electronic data transfer and electronic field-based data entry highlighted in the data collection section contribute to overall efficiency. Customizable data query for export from a live system eliminates staff burden for data requests and reduces time for end-users to receive and manipulate data for analysis. One-stop portals reduce the time users spend on searching for data, allowing for more in-depth analyses that were once prohibited by time constraints. Centralized tools give all users access to analytical capabilities, reducing resources required at the local and regional levels and allowing these resources to be better allocated into the safety environment.

Arizona has opportunities to improve the overall efficiency. Several agencies enter incident records into their own systems, then the same record is reentered into ALISS, duplicating effort. Electronic data transfer would minimize repetitive entry, thus saving significant resources. Deploying field-based electronic data entry for officers would reduce the duplication of effort by the data entry staff and would improve efficiency. A one-stop portal for data download would free staff resources now used to query and export data for local, regional, and national users. The integration of online tools would reduce software licensing costs and provide greater accessibility to a larger number of users, thus creating a safer environment for all.

4.6 GAP ANALYSIS RESULTS

The following sections give the results from the gap analysis with the results of the internal desires section of the use case. While Arizona's crash data community utilizes a few best practice elements, several gaps remain to be filled (Table 8). Table 8 highlights the areas where improvements are needed to bring Arizona up to the best practice levels for crash data

Table 8. Gap Closure

Best Practice	ADOT Current Practice	Gap Closure
Field-based electronic data collection	Phoenix only, rest of state uses paper data collection	Promote more field-based electronic data collection
Business attribute rules and domains for QA/QC	Some domains and business rules	Expand where applicable
Automatic data entry from external database	None	Need to integrate external databases and utilize swipe cards or barcode scanners
GIS or GPS locating in field unit	None	Need to deploy GIS of GPS to field for incident locating
MMUCC standards	Essentially Compliant	Meets Best Practice
Electronic data transfer of incident records	None	Need to promote electronic data transfer of incident records
Utilize RDBMS	Utilize RDBMS	Meets Best Practice
Link or relate other enterprise databases	None	Need to integrate other enterprise databases
Live access to central repository for incident records	None	Need to make database accessible to users
Custom ad-hoc reports or access to previously generated reports	Can be requested from Traffic Records	Need to give users access to this functionality
Custom data queries	Can be requested from Traffic Records	Need to give users access to this functionality
Export data in multiple formats	Can be requested from Traffic Records	Need to give users access to this functionality
User-defined export formatting	None	Need to give users access to this functionality
User-friendly GIS for analysis and reporting	User-friendly GIS, however ALISS is not GIS Friendly	GIS Meets Best Practice, but ALISS needs GIS improvements
Advanced charting, graphing and statistical analysis	Users must rely on their own software packages	Better access to tools would be beneficial
Access to external data sources	Access is available via the data warehouse	Better, more integrated access would be beneficial
One-stop portal for information	Data Warehouse provides access to ADOT users	Provide access to the rest of the crash data community
Centralized Web-based application	None	Need to create portal
Security for sensitive information	Sensitive information not available	Create access to data and generate security requirements
Access to live data and databases	None	Grant access to user community

systems. The results are divided into the five best practice components. These results are in the technical memorandum portion of the study for inclusion into the system designs and overall recommendations.

4.6.1 Data Collection

Arizona should utilize electronic, field-based data entry and electronic data transfer. This effort should include the creation of browse lists of standard terms and business attribute rules for automated QA/QC and standardization of data elements. Global Positioning System receivers and a geographic information system should be field-deployed to each officer's laptop computer to use in recording the X,Y coordinates of incident locations, which should be stored with each incident record. This will improve the accuracy of positional data in the database. External database systems, such as those for vehicle registrations and driver's licenses, should be integrated with the system to minimize manual data entry. Additional MMUCC data elements should be collected at the scene, including first and second harmful events. The user community should standardize data elements for street naming and crash definitions. Signalized intersections and road contract release dates should be collected and maintained.

4.6.2 Data Storage

Arizona should integrate additional data sources into ALISS. The State Highway System Log should be the primary source from which facility information is attached to the incident record, which would allow statewide averages to be calculated. Driver's license, vehicle registration, weather, traffic volume, and other databases should also be integrated into an enterprise system of transportation-related databases. ALISS needs detailed system documentation and the ability to manipulate the database structure and a Visual Basic data entry form to allow for any changes in the future.

4.6.3 Analysis and Reporting

Arizona should automate its data reporting and exporting routines, giving users direct access to the live system and allowing for customizable data export formats. On-line functionality should be improved to include GIS, advanced statistical analysis, and graphic and charting capabilities. This on-line access point should be built as a one-stop access point for data and analysis, including digital ALISS reports and automated FHWA and FARS reporting. The system should allow generation of statewide averages by facility type, identification of top 10 crash locations for a given area by type of crash or type of facility, identification of high risk / high hazard locations, the ability to assess the effectiveness of an improvement, accident and severity rates, and Intersections Magic diagramming. Basic and user-friendly GIS diagramming and mapping should also be a functional element.

4.6.4 Accessibility

Arizona should grant access to all users within the crash data community through an Internet-based application and a one-stop portal for data access and analysis. A 24/7 solution would provide the greatest access and flexibility for end users.

4.6.5 Overall Efficiency

Arizona should eliminate redundant and duplicate data entry. Online and customizable data download, centralized access to tools and data, and live linkages for custom reporting will minimize staff intervention at all levels.

Inter Tribal Council of Arizona (ITCA)

According to Esther Corbett of the Inter Tribal Council of Arizona (ITCA), only a few of the 21 Native American tribes in Arizona provide regular FARS data, and most do not have facilities to keep crash records. What exist are paper records. Tribes have been willing to participate in studies, but have received no benefit from the studies. Therefore, they are reluctant to participate in further activities.

ITCA did a multidisciplinary study of 3 tribes, and as a result obtained $12,000 for implementation of a POLARIS Crash System and an Access Database Management System. The Navaho Nation has since implemented a database and has a Highway Safety group, but how the data is distributed or used beyond internal tribe postings is not well documented. Their website is: www.navajo.org.

Law enforcement and public health agencies on the reservations are other hurdles to data collection. The tribes and the Bureau of Indian Affairs (BIA) law enforcement officers use the standard Arizona Highway Patrol (AZ HP) accident report forms. However, record keeping on crashes is sporadic for both types of agencies. Another possible way of gaining the information is from hospital records of the Indian Health Services, however some tribes have started their own hospitals, which complicates data collection. The BIA has a Road Inventory, however tribes do not have access to it.

ITCA feels that the tribes need to be informed of the importance of crash data for planning and funding of activities. If the tribes can be persuaded to collect and provide the data, then Memorandums of Understanding can be executed for data sharing.

4.7 GAP ANALYSIS CONCLUSION

Arizona's crash data community has a significant number of desires and therefore requires an advanced system to meet them. The results of the best practices, use case, and the gap analysis have highlighted the general system requirements for a best practice system for Arizona. These system requirements are fed into the final portion of this study, the technical memorandum, where the desires are weighed against the practicality and the costs associated with meeting them. All practical components are investigated and detailed to allow ADOT to weigh all options before deciding where to proceed in addressing the desires of the crash data community. The specific components are outlined with a cost estimate and roadmap for their implementation, as well as an overall system design.

5. TECHNICAL MEMORANDUM

This technical memorandum proposes ways to meet ADOT's desires and provide solutions to the gaps identified during the previous portions of this study. An overall systems design strategy as well as individual system components are discussed to provide ADOT with specific courses of action to reduce the resources needed in the collection and analysis of crash data. The benefits, components, implementation steps, and costs associated are all outlined below.

5.1 INTRODUCTION

This memorandum addresses four overall goals. These four goals follow the same categories discussed throughout the study: Data Collection, Data Storage, Analysis and Reporting, and Accessibility. The fifth goal of overall efficiency will be met with the achievement of the other four goals. For each goal specific system components are given that help achieve the best practices. Once each component has been discussed, an overall system design is described that is an inclusive solution to all the desires of the crash-data community.

The study team realizes that a comprehensive solution is probably not economically feasible for ADOT, and the final section of this report gives implementation steps by their recommended priority. This technical memorandum allows ADOT to pick and choose individual components to meet its desires. The section on each component has a very rough estimate of the costs associated with implementing that component. Dollar figures are estimated from the cost an outside firm would charge for these services and do not reflect any costs that could be saved by having DOT staff perform some or all of the tasks.

The technical memorandum portion of this report does not constitute the formal recommendations of the study team. The formal recommendations and their costing are outlined in the final section of this report - **Recommendation and Implementation Strategy**.

5.2 OVERALL GOAL – MORE EFFICIENT AND ACCURATE DATA COLLECTION

5.2.1 Solution: Electronic Data Entry (EDE)

Benefits

EDE optimizes data collection by digitally capturing information at the incident location. Digitally collected information at the incident location minimizes the chance of interpretation errors when the officer returns to the office to enter the information. EDE reduces data collection and entry time by inserting information directly into a system. The time needed to collect information is also reduced by the use of domains (pick lists), minimizing the amount of information that must be typed into the system. These domains also promote data accuracy and consistency by eliminating typing errors and variations such as “Ave” or “AV” in abbreviations for “Avenue.” EDE allows for numerous other capabilities that can improve data collection, such as electronic data transfer, automatic data entry from other data sources, and GIS/GPS integration. Most incident responders already have a computer, and this functionality can be developed within that context. This should require minimal amounts of new equipment acquisition.

Components

EDE requires that a field response unit have either a laptop computer or a handheld device for data entry. An application is required for a data entry form and the storage of the record once it is entered. This application should be developed with domains and business attribute rules for data standardization and validation. The application will also need an export function to transfer the electronic record to the local agency’s database or to ADOT directly.

Implementation

To properly implement this component, a laptop computer or a handheld device must be deployed to any individual who responds to incidents. Therefore, an inventory must be taken to identify the number of new hardware units required. The inventory should also include the type of units in the field, as that will be critical in the software development. Next, an application needs to be developed that works on the many platforms already in existence. The application should be very user-friendly and should utilize domains and business attribute rules for data consistency and validation. The export routine should have both hardcopy and digital capabilities to support the needs of any organization. The software should be tested prior to a full implementation. Users will require a small amount of training to properly utilize the system.

Costing

Table 9 shows the estimated costs of implementing electronic data entry.

Table 9. Costing – Electronic Data Entry

Component	Cost
Hardware inventory	$20,000
Hardware (computer)	$2,000/ea
Hardware (Personal Digital Assistant (PDA)	$750/ea
Custom data-entry and storage software	$65,000
Domains & business attribute rules	$20,000
Export routines	$25,000
Installation	$100,000
Training	$75,000
Total (not including hardware)	**$305,000**

5.2.2 Solution: Electronic Data Transfer (EDT)

Benefits

Electronic data transfer eliminates the need for duplicate data entry by automatically sending the electronic incident record to the local database and to ADOT's incident database. This component should be enabled with electronic data entry. This component can be configured to transmit an incident record instantaneously after it is created through the use of radio telemetry, cell phones, or satellite-based Internet, or the records can be transmitted at the end of a shift when the officer returns to the office and connects to a wireless LAN.

EDT can still be implemented if a municipality's police department does not use field EDE, but has its staff enter incident information at the office when officers return. When the records are entered into the local system, the municipality can send ADOT an electronic copy via the Internet instead of sending hardcopies. The municipality can send records individually or as a batch.

Components

EDT requires that Electronic Data Entry has been enabled in the field or that incident records are entered into a database system at a local office. A small export routine is required to package incident records into a format that can be transferred. For ADOT to implement EDT, it needs a small import routine that will accept the export and correctly load the record into the ADOT database. ADOT will need to establish a staff workflow routine to verify that records are being sent to ADOT and are being correctly imported into the system.

Implementation

To implement EDT, agencies must first implement Electronic Data Entry at either the office or in the field. A small study will need to be undertaken to inventory the data-collection methods of each response unit within the state. This study will identify the number of different systems within the state for which export routines must be created. The small export routine will package each record into a transferable file. There are multiple methods that can transfer the file to ADOT's database for import. A small import procedure needs to be created to accept and import the records.

Costing

Table 10 shows the estimated costs.

Table 10. Costing – Electronic Data Transfer

Component	Cost
Data-collection inventory	$25,000
Export routine	$20,000
Import routine	$25,000
Installation	$100,000
Training	$50,000
Workflows	$10,000
Staff @ 10 hours/wk	$20,000
Total	**$250,000***

*Training and installation costs can be eliminated by implementing at the same time as electronic data entry.

It is anticipated that one staff member will be required to facilitate Electronic Data Transfer. This position will probably require 10 hours per week to ensure that transfers are properly entering the system. A successful candidate for this position should have one year of database experience and an understanding of crash data for QA/QC procedures.

5.2.3 Solution: GIS/GPS Integration

Benefits

Integrating GIS and GPS can greatly improve the accuracy of incident locations. Only the officer in the field knows exactly where the incident occurs, and he or she should be the one to enter the precise location of the incident on the record. GPS can provide the exact X,Y coordinates to enter onto the form, or a GIS can be used to find the exact location. Using GIS also brings general GIS functionality to the officer in the field for other activities, such as routing, base map information, and other analytical capabilities. A GIS can be integrated into the existing field-based computing hardware within the response vehicle. It can put aerial photography, infrastructure information, and crime data at the responder’s fingertips. Free GIS reader software can be deployed to users with no additional licensing costs.

Components

A GIS requires a laptop computer or a handheld computing device to operate. It also requires a small software application and a published data package for the user. A customized application will need to be written to easily return the X,Y coordinates of a location for input on the incident record. GPS requires a GPS receiver (hardware) on each response unit. No customized software is required.

Implementation

To implement a GIS, data must first be acquired to create base maps for responders to use. Either an application needs to be written to easily return the X,Y coordinates of a selected location, or, with appropriate training, a user could obtain the X,Y coordinates from the existing GIS software. The software and data need to be bundled for distribution and installed on the field units. Staff training is required, as well as periodic updates to the base maps and aerial photography.

To implement GPS, receivers must be purchased for each responder's vehicle. Minimal training will be needed to properly operate the GPS receiver and retrieve X,Y coordinates.

Costing

Table 11 shows the costs for implementing a geographic information system; Table 12 shows costs for implementing use of the Global Positioning System.

Table 11. Costing – GIS Implementation

Component	Cost
Data acquisition	$15,000
Base map creation	$15,000
Software customization	$20,000
Installation	$100,000
Training	$50,000
Update	$10,000/6 months
Total	**$200,000***

*Training and installation costs can be eliminated by implementing at the same time as electronic data entry.

Table 12. Costing – GPS Implementation

Component	Cost
GPS Receiver	$400/ea.
Installation	$100,000
Training	$50,000
Total	**$150,000***

*Training and installation costs can be eliminated by implementing at the same time as electronic data entry.

5.2.4 Solution: Model Minimum Uniform Crash Criteria (MMUCC)

Benefits

Implementing MMUCC will ensure that the appropriate information is collected for each incident. This will also ensure that all FHWA and FARS requirements are met and that Arizona's data can be directly compared with and analyzed against data from other states that utilize MMUCC standards. In addition, all of Arizona's incident data be collected for the same data elements across the entire state. MMUCC data elements can be included with additional data elements and utilized within an EDE environment.

Components

MMUCC has no required components except that data elements actually be recorded electronically or on paper.

Implementation

To implement the MMUCC standards, a small study needs to be undertaken to investigate the data elements that Arizona already collects and compare them with the MMUCC elements. The results should then be passed to the EDE system for inclusion into the design of the data-entry system.

Costing

Table 13 shows the costs for MMUCC data elements.

Table 13. Costing – MMUCC Data Elements

Component	Cost
Comparison Study	$10,000
Total	**$10,000**

5.2.5 Solution: Automatic Data Population

Benefits

Automatic data entry reduces the amount of time required to collect all the necessary information at an incident location. It also ensures data quality. By utilizing data that has already been entered into another source, data elements will conform to a standard and there is no chance for entry data error on the officer's part. Data such as driver, vehicle, and location information can be automatically populated from the Motor Vehicle Division (MVD) databases and GIS/GPS systems. Automatic data entry can be utilized in the field or can occur by using driver's license numbers and license plate numbers when submitting the record to the incident record system. Most response units will already have capabilities to retrieve driver records and vehicle information by entering information for citations. The information can then be used for integration into the incident report, minimizing data entry and insuring accuracy.

Components

To implement automatic data entry, EDE must be enabled. Automatic data entry also requires a capability to retrieve driver and vehicle information from a remote database. The crash-data collection system will then need customization to retrieve the information and populate the appropriate data elements. A custom tool will also need to be developed to retrieve X, Y coordinates from a GIS or GPS system.

Implementation

Automatic data entry would best be used if created in conjunction with EDE. A small study will need to be undertaken to identify all the data elements that can be populated from remote databases and the methods by which these elements can best be used to populate the current crash-data system. Custom software will then need to be developed to integrate the remote databases with the data-entry form. Custom software will also need to be developed to integrate GPS/GIS into the automatic data entry scheme. Minimal training will be needed to utilize the system. Cooperation will be needed between the responders and the maintainers of the driver's license and registration databases to minimize complications if the databases change.

Costing

Table 14 shows the costs for implementing procedures for automatically entering data.

Table 14. Costing – Automatic Data Population

Component	Cost
Utilization study	$25,000
Driver's license integration	$30,000
Registration integration	$30,000
GIS/GPS integration	$30,000
Installation	$100,000
Training	$50,000
Total	**$265,000***

*Training and installation costs can be eliminated by implementing at the same time as electronic data entry.

5.2.6 Solution: Domains and Business Attribute Rules

Benefits

Like automatic data entry, domains, or a list of possible attributes, and business attribute rules minimize the amount of information the responder enters, force consistency among data element responses, and reduce the possibility of error in data entry. The rules can help identify when information is inaccurately entered, and the responder can correct the problem at the scene while the correct information is still available. Domains and business attribute rules also reduce the level of quality assurance/quality control work needed for a record.

Components

Electronic data entry must be implemented. Small customizations to the data entry form will be required.

Implementation

Domains and business attribute rules should be created and utilized during the development of an EDE system. A small study will need to be undertaken to highlight all the possible domains and attribute rules available for use. Small customizations to the data-entry form will be required. These customizations will need to be replicated across all incident-record databases to help ensure consistency throughout the entire system.

Costing (Table 15)

Table 15 shows the costs for implementing domains and business attribute rules for data entry.

Table 15. Costing – Domains and Business Attribute Rules

Component	Cost
Utilization study	$25,000
EDE customization	$15,000
Replication across databases	$15,000
Total	**$55,000**

5.2.7. Solution: Crash Definition Standards

Benefits

The benefit of standard crash definitions is that all responders, analysts, and decision-makers call the same type of crash the same thing. This will help minimize inaccurate data analysis based upon incorrect data entry.

Components

Crash definition standards training and a look-up field manual for responders are desired.

Implementation

First, the crash-data community must agree on crash definitions. Then, the definitions must be passed throughout the community by training and reference material for all responders.

Costing

Table 16 shows the costs for developing and implementing crash definition standards.

Table 16. Costing – Crash Definition Standards

Component	Cost
Community agreement meetings	$20,000
Publications	$50,000
Training	$50,000
Staff	$65,000
Total	**$185,000***

*Training costs can be eliminated by implementing at the same time as Electronic Data Entry.

It is anticipated that one staff member will be required to manage Crash Definition Standards. This position should be full time to ensure that proper training is provided to all data collectors. A successful candidate for this position should have two years of general experience in working with crash related data.

5.3 OVERALL GOAL – ENTERPRISE DATABASE SYSTEM INTEGRATION

5.3.1 Solution: Create a new ALISS

Benefits

Currently, ALISS has no documentation and is not customizable. The creation of a new system will eliminate these problems as well as providing the ability to integrate other functionality. GIS has evolved over the years into a transparent database system that allows users with no GIS knowledge to utilize a RDBMS without even realizing that they are using a GIS system. By utilizing SQL Server or Oracle, databases users can continue to work in a RDBMS environment while achieving robust GIS functionality. ADOT already has all the necessary licensing to utilize GIS and RDBMS, so no additional software is required. By creating a new system, ADOT will also be developing an enterprise system that can integrate with multiple other databases, providing the necessary linkages for advanced analysis and query. This integration will substantially increase analysts' capabilities as well as provide a much more robust system for ADOT. A new system can take advantage of electronic data transfer domains and business attribute rules, and automatic data population. A new system will also allow for more efficient reporting and better data export routines. It will have the capabilities for users to access the data live.

Components

A new ALISS will require a robust server environment capable of handling multiple concurrent users for data entry, query and export, and that has minimal downtime. Software will be an integral component. An RDBMS with several customized applications will be needed as well as an advanced security scheme for data access. The database will need import and export routines, data-entry forms, stored queries and reports, and integration with other databases.

Implementation

First, the new ALISS needs to be designed to integrate other databases. Incident records will then need to be transferred into the new system. Checks need to be administered to ensure data is not lost or altered in the conversion process. Import and export routines will need to be written to minimize staff involvement for data requests. Reports currently stored in the ALISS will need to be migrated to the new system. A new security scheme will need to be created and implemented for all users who have access to the system. A data-entry program needs to be created for records that are not transmitted through EDT. A data-export and query interface should be created to give analysts direct access to incident records. System documentation is needed to allow for future development. Staff training will be needed for those who have frequent interaction with the system, and a user's manual should be created.

Costing

Table 17 shows the estimated costs of a new Accident Location Identification Surveillance System.

It is anticipated that one staff member will be required to manage the new ALISS. This position should be full time to ensure proper database and data entry administration. A successful candidate for this position should have three to five years of experience in data entry and administration and a general understanding of crash data reports.

Table 17. Costing – New ALISS

Component	Cost
Database design	$35,000
Data migration	$30,000
Import and export routines	$15,000
Report generation	$35,000
Data-entry form	$25,000
Security scheme	$10,000
Query and export interface	$20,000
Documentation	$5,000
Training	$10,000
Staff	$85,000
Total	**$270,000**

5.3.2 Solution: Link State Highway System Log to New GIS Incident Record Database

Benefits

Linking the State Highway System Log with the incident records database through the ADOT Information Data Warehouse (AIDW) will allow users to analyze the relationship between facility information and incidents, thus allowing them to determine accident rates and averages. By default, this will also integrate the new ALISS with the existing GIS resources available from the GIS group. This linkage will bring the ALISS into the enterprise design, allowing ADOT users to query and export information.

Components

Integration is dependant on a new ALISS. No additional components are required.

Implementation

To implement, the new ALISS needs to be replicated in the AIDW. This will link these systems for download and analysis. The security schema may need altering to include any sensitive information contained in the ALISS.

Costing

Table 18 shows the costs to integrate the State Highway System Log into the new ALISS.

Table 18. Costing – Integrate State Highway System Log

Component	Cost
Security schema	$5,000
Total	**$5,000**

5.3.3 Solution: Data Warehouse Integration

Benefits

The more data to which users have access, the greater their analytical capabilities and the better their decision-making will be. The data warehouse already stores information based upon a route and mile marker. This information can easily be linked to a new ALISS for data query and retrieval. This linkage would provide users with all the information assets currently stored within ALISS, increasing analytical capabilities. Once again, just because the data is queried and stored in a GIS system, users do not need to know the information is in a GIS and do not need GIS skills to utilize the RDBMS functionality.

Components

Integration is dependent on a new ALISS. No additional components are required.

Implementation

To implement, the new ALISS needs to be replicated in the AIDW. This will link these systems for download and analysis. The security schema may need altering to include any sensitive information contained in the ALISS.

Costing

Table 19 shows the costs of integrating the Data Warehouse with ALISS

Table 19. Costing – Integrate Data Warehouse System

Component	Cost
Security schema	$5,000
Total	**$5,000**

5.3.4 Solution: Digital Incident Report Storage

Benefits

Digital storage and retrieval of hardcopy incident records is significantly more efficient than the current system of microfilm. Digital storage will decrease response time and minimize staff involvement in document retrieval. This new method would not increase staff involvement in creating the digital report, as the current methods for capturing the document are very similar to those required to store a record digitally. Several off-the-shelf applications exist for digital document management. These applications can also be linked to the enterprise solution for easy query and retrieval. The electronic record in the system can be directly linked to the scanned hardcopy for retrieval and analysis. An additional benefit is that ADOT can utilize the document management system for other applications in addition to incident records. Many organizations use these systems in human resources, engineering, and contracting departments. ADOT is currently researching a document management system and should monitor the progress of this study.

Components

Digital storage and retrieval of data requires a document scanner and a document management system. The system must be designed and built for ADOT's needs. It is necessary to integrate the document system and the incident record system.

Implementation

The document management system will need to be designed and built. Old records will need to be transferred into the new system. Hardcopies and electronic records will need to be linked for easy user access. Additional customization of the user interface will be necessary to ensure ease of access to users. The security schema may need altering to include any sensitive information contained in the data warehouse system. Minimal training will be needed for individuals who maintain the document system.

Costing

Table 20 shows the costs to implement the digital storage of incident reports.

Table 20. Costing – Digital Incident Report Storage

Component	Cost
Document management system	$10,000
Document scanner	$5,000
Historic record transfer	$30,000
Document linkage	$10,000
User interface customization	$10,000
Security schema update	$5,000
Training	$5,000
Staff	$75,000
Total	**$150,000**

It is anticipated that one staff member will be required to manage the Digital Incident Reports. This position will should be full time to ensure proper entry, access, and retrieval of records. A successful candidate for this position should have one to two years of general experience in Document Management Systems.

5.4 OVERALL GOAL – IMPROVEMENT OF ANALYTICAL AND REPORTING CAPABILITIES

5.4.1 Solution: Advanced Statistical, Charting, and Graphing Capabilities

Benefits

Advanced statistical, charting, and graphing capabilities will improve the way analysts and decision-makers visualize incident information. These outputs can be included in reports and presentations for better decision-making. These capabilities can provide users with outstanding technical resources coupled with a wide breadth of information for analysis. These capabilities can be integrated directly into the user interface to the database system.

Components

Special software will be needed to provide these functions. Also, the enterprise database should be developed to provide as much information as possible for the analysis. The software should have a live link to the databases for utilization of the most up-to-date information.

Implementation

A study should be undertaken to specifically identify common statistical, charting, and graphing needs. These commonly used processes should then be developed and stored to minimize staff time needed to generate analyses. A custom query engine should also be developed to allow users to create ad-hoc charts, graphs, and statistical analyses. Export routines will need to be generated to allow for these created charts, graphs and statistical analysis results to be included into reports. User documentation should be created to help users interact with the application.

Costing

Table 21 shows the costs of implementing advanced statistical analysis, charting and graphing capabilities.

Table 21. Costing – Advanced Statistics, Charting, and Graphing Capabilities

Component	Cost
Frequently utilized component study	$15,000
User interface	$10,000
Frequently utilized component development	$30,000
Advanced statistical query	$15,000
Charting and graphing query	$15,000
Export routines	$5,000
Training documentation	$5,000
Total	**$95,000***

*Costs can be reduced by utilizing off-the-shelf software.

5.4.2 Solution: User-Friendly GIS Tools

Benefits

User-friendly GIS tools, such as geocoding and corridor analysis, can provide users with advanced analytical capabilities without requiring advanced GIS knowledge. The enterprise database integration will give users access to most data resources within ADOT. These resources can then be leveraged into advanced spatial analysis within a GIS. User friendly tools grant users access and capabilities that would otherwise be too complicated without advanced GIS training.

Components

Tool development requires stable and reliable spatial data coming from a centralized location. GIS software is needed to run these tools. However, with the recent development of ArcIMS, a Web-based GIS application, these tools can be deployed over the Web and no user software is required. Custom programming is required for tool development

Implementation

A needs assessment is needed to identify additional tool development that may be required (some tools are highlighted in the following sections). An ArcIMS Website needs to be developed and connected to the enterprise database. Analytical routines need to be identified and programmed for easy use. Tutorials need to be developed to help users understand the inputs and outputs of the tools.

Costing

Table 22 shows the costs for developing and implementing user-friendly GIS tools.

Table 22. Costing – User Friendly GIS Tools

Component	Cost
Tool development study	$15,000
ArcIMS Website	$25,000
Tool development	$15,000/ea
Tutorials	$5,000
Total	**$45,000***

*ArcIMS Website is a one-time cost. It is included for each item that depends on ArcIMS to portray an accurate cost for a stand-alone installation.

5.4.3 Solution: Signalized Intersections (Data Collection)

Benefits

Information on all the signalized intersections within the state provides users the ability to analyze incidents more thoroughly. Users would be able to identify high crash locations with and without signals. The data for non-signalized intersections can be exported to spreadsheet format for inclusion in signal warrant analysis programs. The database should be integrated with the GIS allowing for GIS analysis of these features as well. More than likely, the regional, county, or municipal governments already have an inventory of signalized intersections. Integration into a statewide database should be possible without field surveys.

Components

Additional staffing may be required to maintain these data once created.

Implementation

The possible sources of information need to be researched. Acquire and integrate intersections data need to be acquired and integrated into the GIS database for use.

Costing

Table 23 shows the costs for creating an inventory of signalized intersections and integrating it into the GIS database.

Table 23. Costing – Signalized Intersections

Component	Cost
Locate data sources	$15,000
Acquisition and integration	$10,000
Total	**$25,000**

5.4.4 Solution: Prioritized Crash Locations (Tool Development)

Benefits

Prioritizing accident locations is an analytical process that almost all safety groups use. The creation of a tool that automatically runs this analysis would minimize staff involvement in the analysis, freeing time for other safety-related matters. The tool could also be set up to run on historical records to help in the analysis of safety improvement effectiveness. The tool can be integrated into an ArcIMS Website to provide all users access. This would also allow the analysis to be run on the live database, assuring that more up-to-date information is used. The analysis can be set up to allow users to choose areas, dates, and other data elements in their analysis. By incorporating this analysis into GIS, the results are displayed graphically, possibly highlighting additional relationships that might not be apparent in a tabular analysis. A statewide top ten crash location list, district top ten crash location list, and top ten angle crash location list are examples of products such analyses could generate.

Components

The enterprise database must be implemented. An ArcIMS Website must be developed and linked to the live database. Custom tool development will be necessary, as well as tutorials to help users with the inputs and results of the analysis. Development should include the ability to export results to aid users in report generation.

Implementation

An ArcIMS Website needs to be developed. The analytical process needs to be defined, and the appropriate queries need to be setup to allow users to set parameters such as date range, accident type, road facility type, fatality, injury, weather conditions, signalized intersection, and vehicle type. A tutorial needs to be created and distributed to users.

Costing

Table 24 shows the costs for developing software to identify locations whose accident rates call for attention.

Table 24. Costing – Prioritized Accident Locations

Component	Cost
ArcIMS Website	$25,000
Define analytical process	$10,000
Tool development	$25,000
Tutorial	$5,000
Total	**$65,000***

* ArcIMS Website is a one-time cost. It is included for each item that depends on ArcIMS to portray an accurate cost for a stand-alone installation.

5.4.5 Solution: High Risk/Hazard Locations (Analysis Capability)

Benefits

Several individuals expressed a need for ability to identify high risk and hazard locations. The need is to be able to identify areas near railroad crossings, truck routes and hazardous materials transport routes near railroads, etc. This analytical capability can be available simply by integrating railroad facility information into the GIS system. This capability would then become available for all to use and analyze. Most of these data should already be in existence, and the effort should be minimal.

Components

This capability requires the enterprise database be made and railroad facility information be included. Railroad crossing information and truck routes are also necessary.

Implementation

It needs to be verified that the necessary railroad, crossing, and truck information has been collected and is accurate. These data have to be integrated into the GIS database. These data need to be made available to all users for analysis.

Costing

Table 25 shows the costs of entering data on high risk and high hazard locations into the GIS database.

Table 25. Costing – High Risk/Hazard Accident Locations

Component	Cost
Data verification	$10,000
Data collection (if necessary)	$20,000
GIS integration	$15,000
Total	**$45,000**

5.4.6 Solution: Safety Improvement Effectiveness (Analysis Capability and Data Collection)

Benefits

The ability to measure the effectiveness of a safety improvement will help direct funds to achieve the most beneficial improvements where they are needed most. This will greatly improve the overall effectiveness of the resources spent for incident mitigation. Integrating safety improvements and incident records into the enterprise database will allow this analysis by generating averages prior to and after an improvement. This will also allow for comparison of improvement rates among similar areas that have had different improvements, leading to the determination of the most-effective improvements. Analysis could be performed to look at the crash rates for the three years prior to the countermeasure and for three years after. A tool could be developed to automate this analysis. More than likely, much of the data already exist.

Components

A database of all safety improvements, including type and date installed, is necessary. The ability to determine accident rates by time period, accident type, and vehicle type is required. Additional staffing may be required to maintain safety improvement data.

Implementation

A small study should be undertaken to research the availability of safety improvement data. Needed safety improvement data should be collected, and all should be integrated into the GIS system.

Costing

Table 26 shows the costs of gathering data on safety improvements and integrating that data into the GIS.

Table 26. Costing – Safety Improvement Effectiveness

Component	Cost
Data availability study	$10,000
Data collection (if necessary)	$30,000
GIS Integration	$15,000
Total	**$55,000**

5.4.7 Solution: Accident and Severity Rates (Analysis Capability)

Benefits

The ability to generate crash rates for facility types (2-lane, 4-lane, etc.), urban vs rural, and other criteria, at statewide and local levels allows the comparison of a selected road segment's Accident or Severity Rate to be compared to statewide and local area rates. This can help analysts measure problematic areas to determine the need for safety improvements. By integrating the data into the enterprise system, users can display these rates in a graphical format within the GIS. The GIS can help identify locations as well as corridors that have higher rates.

Components

To generate accident rates and severity rates, facility information and incident information need to be linked and must be able to be cross-queried. The enterprise database design needs to take into account the storage of statewide, countywide, municipal, and facility accident rates by vehicle and accident type. A tool needs to be developed that frequently regenerates accident and severity rates at the varying geographic levels. This tool can run in the background of the database and require no staff interaction.

Implementation

Prior to the creation of a traffic crash database, an intensive design process should be undertaken to ensure that the data is stored efficiently to optimize analysis and update routines. This database should be integrated into the GIS system, then a tool created to automatically calculate accident and severity rates from the data.

Costing

Table 27 shows the costs for adding the capability to generate accident and severity rates within the system.

Table 27. Costing – Accident and Severity Rates

Component	Cost
Rate needs study	$15,000
Database design	$15,000
Rate maintenance tool	$15,000
Documentation	$5,000
Total	**$50,000**

5.4.8 Solution: Street Names and Aliases Database (Data Collection)

Benefits

There is a recurring problem in which streets have both a name and a local alias name in incident queries. A user can query for a name and end up not selecting all incidents for that location due to some incidents' being recorded with the alias name. Integrating the GIS system will help mitigate this problem, but including alias names in the database design will eliminate this problem completely.

Components

The enterprise database should be designed to incorporate the use of alias names during queries based upon road names.

Implementation

The database needs to be designed with alias tables and look-ups for street names. Data will need to be collected for all street names and their aliases.

Costing

Table 28 shows the cost of creating a street names database.

Table 28. Costing – Street Names and Aliases

Component	Cost
Database design	$10,000
Data collection	$25,000
Total	**$35,000**

5.4.9 Solution: Contract Release Dates (Data Collection)

Benefits

The inclusion of road contract release dates, or dates when roads were opened to public use, will serve two main purposes: 1) road widening will be reclassified on the specified date to be included in the proper category (say 2-lane to 5-lane), and 2) the opening of new facilities increases the mileage of a category, and it is important to know how long the road has been in existence. This improves the accuracy of the analytical processes being used.

Components

Contract release dates need to be included into the database.

Implementation

Contract release dates need to be acquired for roadways and integrated into the database.

Costing

Table 29 shows the costs of creating a database of contract release dates.

Table 29. Costing – Contract Release Dates

Component	Cost
Data collection	$15,000
Data integration	$15,000
Total	**$30,000**

5.4.10 Solution: Data Sharing Among ADOT, Local, and Regional Agencies

Benefits

Agencies across the state collect many types of traffic accident data. These data are often more accurate than the data that ADOT stores in its databases and data warehouse. Data-sharing and cooperation can bring these updated resources into the enterprise system, making the most accurate and up-to-date resources available for analysis.

Components

Additional staff is necessary to consistently research new data-collection efforts throughout the state. Staff will also be required to integrate this information into the enterprise system and to update it.

Implementation

Adequate staff time should be dedicated to acquiring and integrating updated data resources.

Costing

Table 30 shows the costs of creating a system to allow for data sharing amongst and between Arizona State, local and regional agencies.

Table 30. Costing – Data Sharing Amongst ADOT, Local, and Regional Agencies

Component	Cost
Staff	$40,000
Total	**$40,000**

It is anticipated that one staff member will be required to promote data sharing. This position should be full time to ensure that data is properly shared amongst agencies. A successful candidate for this position should have two years of general experience in database and an understanding of transportation data.

5.4.11 Solution: Intersection Magic Integration (Analysis Capability and Tool Development)

Benefits

Many users utilize Intersection Magic (IM) to portray intersection incidents in reports and for analysis. Getting incident information into Intersection Magic is time-intensive and requires staff knowledge of the software. Recent updates of Intersection Magic have enabled the Internet and enterprise database systems to push IM capabilities to users through the Web. IM can now be integrated directly with an ArcIMS Website and an enterprise database to provide all users with access to this functionality without the need of their formatting data or their having to know IM software. Users also get to use the live database environment, ensuring up-to-date and accurate data are used. Implementing this technology would eliminate the need for individual agencies to maintain licenses for IM and would grant access to users who previously could not use this functionality due to lack of funding or software knowledge.

Components

This requires the Intersection Magic Web application and an ArcIMS Website. Both applications need to be linked to the enterprise database. A small, customized application needs to be built to allow users to query for an intersection, date range, and incident types and to transfer a selected set to and from the applications. Tutorials will be needed to help staff understand the capabilities and results of this tool.

Implementation

An ArcIMS Website should be developed to allow users to select parameters and data records for the creation of intersection diagrams. A small interface will be needed to transfer the selections to the IM application. The Intersection Magic application will need to be installed and customized. Tutorials should be created to assist users in utilizing the IM tools.

Costing

Table 31 shows the cost of integrating Intersection Magic into the system.

Table 31. Costing – Intersection Magic Integration

Component	Cost
Intersection Magic software	$100,000
ArcIMS Website	$25,000
Application interface	$15,000
Tutorial	$5,000
Total	**$145,000***

*ArcIMS Website is a one-time cost. It is included for each item that depends on ArcIMS to portray an accurate cost for a stand-alone installation.

5.4.12 Solution: Harmful Events (Data Collection)

Benefits

By making Second, Third, Fourth, and Most Harmful Event data fields available, users will be able to incorporate them into their analyses of accident causes and safety mitigation. (First Harmful Event is already collected on the Crash Form)

Components

ADOT will need to hire or reallocate staff enter the Harmful Events data for each accident into the Accident database. These data elements are interpretive and it is not feasible to train all responding officers in how to derive these data elements; it is therefore ADOT's responsibility to correctly enter these elements into the Accident database. Staff will need to be trained for this.

Implementation

Workflow procedures will be needed to populate these data elements. Training will also be needed to help staff understand the appropriate usages of these values.

Costing

Table 32 shows the costs of including data on most-harmful events in the system.

Table 32. Costing – Most Harmful Events

Component	Cost
Training	$80,000
Total	**$80,000**

No additional ADOT staff will be needed, however training resources will be required to educate data collection personnel and analysis personnel.

5.5 OVERALL GOAL – MORE EFFICIENT DATA AND ANALYSIS ACCESS

5.5.1 Solution: Web Portal and Data One-Stop

Benefits

A Web portal confers many benefits on the crash data community. The first and foremost is that users are given live access to ADOT's data resources. If built correctly, a Web portal can eliminate the "middle man" in getting information to and from users. Data query and export routines give users instantaneous access to data rather than having to request data from ADOT and ADOT staff having to generate a query and send the data to the user. If built upon an enterprise database, the Web portal can easily become a data one-stop for information as well. Information is linked and accessible for the same query and export routines and can be used to acquire any information within the enterprise system, not just incident records. A Web portal can serve as an analysis point for users. Analytical tools such as GIS, Intersection Magic, statistical analysis, charting, graphing, and report generation can be integrated into the Web portal, creating a unique and robust access point for analysis and information. The data warehouse, already in existence, approaches this theme, but is unavailable to most of the crash data community. A Web portal would open up all these data resources to the entire community. ADOT can implement security schemes to allow or restrict access to the various analytical tools and data resources. Funding and staff resources at smaller agencies limit users' ability to effectively perform safety analysis and suggest improvements. Introducing a Web portal and data one-stop with robust analytical capabilities would substantially free resources, allowing them to be reallocated to other safety-related activities. Substantial funding at these agencies goes toward maintaining GIS, Intersection Magic, and other applications. Some agencies simply cannot afford these applications and have to make do without. By making these tools available on the Web, agencies will not need to maintain their own licenses and access will be provided to groups without these capabilities. Web analytical tools will also reduce the staff involvement in answering requests for data and processing data for analysis. These data will already be available for analysis with no manipulation from the user's perspective.

Components

A security scheme is needed. A Web application and a user-friendly interface need to be designed and built. GIS should be a strong component for querying, exporting, and analyzing data resources. Analytical tools for users should be developed within the application.

Implementation

A study should be undertaken to outline the entire implementation of the Web portal and data one-stop. The first step will be to make the data available through the AIDW. The Web portal then needs to be designed as a component-based system for the various functions available within the system. The design should have a start location that is easy to navigate for users to select the type of activity they want to pursue; data query and export, analysis, general data access, and help. The data query and export section should allow users to select the dataset to query and specify any number of parameters for the query. Users should also have the ability to select and query any additional, related information from the enterprise system. In the analysis section, users should have the capability to select stored analysis procedures for prioritized incident locations, accident and severity rates, Intersection Magic, and others, or they should be able to perform custom analyses using all the resources in the enterprise system. The general data access section should allow users to display data though a GIS system for general information and report graphics. The help section should outline all the analytical tools and outputs, including general documentation for using the entire site and data restrictions. A security system then needs to be implemented to restrict a user's access to sensitive information or to certain analytical routines. Once developed, the site should be tested thoroughly before being released to the general community. Staff will be required to maintain the site and database as well as to provide user support through the beginning stages because users will likely need help to become familiar with the system and its resources.

Costing

Table 33 shows the costs for developing a Web portal and data one-stop.

Table 33. Costing – Web Portal and Data One-Stop

Component	Cost
Implementation study	$20,000
ArcIMS website	$25,000
Stored analytical tools	$25,000/ea
General analytical capabilities	$30,000
Intersection Magic	$100,000
Data query and export tools	$35,000
General GIS data-mapping	$15,000
Help and tutorials	$15,000
Security scheme	$15,000
Staff	$85,000
Total	**$340,000**

It is anticipated that one staff member will be required to manage the Data Portal. This position should be full time to ensure that proper maintenance is being performed. This position requires three years' experience and an understanding of transportation data and internet applications.

5.5.2 Solution: Custom, Stored, and Historical Reports

Benefits

Custom, stored, and historical reports currently are available by requesting them from ADOT staff. This process can be made much more efficient by making this capability available via the Web. This would allow users access to these reports without any ADOT staff interaction. This report function can be programmed into the enterprise system and can be executed through a Website interface, rapidly returning the report to the user.

Components

Report queries must be programmed into the database. Execution statements must also be programmed to allow users to run the report on the database. Functionality should include exporting the report for users to utilize.

Implementation

Reports from the ALISS need to be replicated in the new enterprise system. A Web interface should be created to allow users access to execute the stored analyses and to access historical reports. Added functionality should be created to allow users to define their own report parameters. Export functionality should be created for users to utilize the report results. A security scheme should be created to limit users' access to sensitive data elements.

Costing

Table 34 shows the costs of making custom, stored and historical reports available on the web.

Table 34. Costing – Custom, Stored, and Historical Reports

Component	Cost
Report programming	$25,000
Web access	$10,000
Custom reports	$15,000
Export routines	$10,000
Security scheme	$10,000
Total	**$70,000**

6.5.3 Solution: User Defined Data Export Formatting

Benefits

Many users request data from ADOT and then spend significant resources manipulating data formats to feed into their analytical programs. Allowing users to define their data-export format requirements will greatly reduce end-user effort.

Components

A Web portal is necessary to provide users with access. A custom interface needs to be developed to allow users to select data-export formatting. Custom database scripts need to be created to translate the users' requests into queries that the database can handle. A security scheme needs to be developed to limit access to sensitive data.

Implementation

A Web portal must first be provided to grant users access to the database. An interface must be deployed to collect formatting requirements specified by the data requestor. Custom database programming can then handle the formatting request. A security scheme must be implemented to limit access to sensitive information.

Costing

Table 35 shows the costs of providing user-defined data export formatting.

Table 35. Costing – User Defined Data Export Formatting

Component	Cost
Web interface	$15,000
Database programming	$15,000
Security scheme	$10,000
Total	**$40,000**

5.6 IDEAL SYSTEM DESIGN

This proposed ideal system is an optimal design comprising all components and needs identified in the best practices, use case, and gap analysis studies. While this system is inclusive of all aspects, it is understood that the total implementation may not be practical due to funding limitations. The system identified below is an ideal system in an unrestricted funding environment (Figure 6). The top recommendations summary section discusses a prioritized approach to staging the proposed ADOT systems and technology design.

5.7 OVERALL IDEAL SYSTEM DESIGN IMPLEMENTATION

While this system may not be fully implemented, it is necessary to examine the logical order of development needed to make each component available to users. The implementation steps below outline the order of implementation for a system to be properly developed.

First, a new ALISS needs to be designed and implemented utilizing GIS database software. ALISS data must then be migrated, if necessary, into the new system and links established where migration is not necessary. A security scheme then needs to be developed to grant and restrict access to appropriate user groups for all sensitive data within the enterprise system.

Once the system is running, development of a Web-based Internet application should be undertaken. The Web application should be component-based so that components can be developed individually. The outer framework should be developed first. The data-access

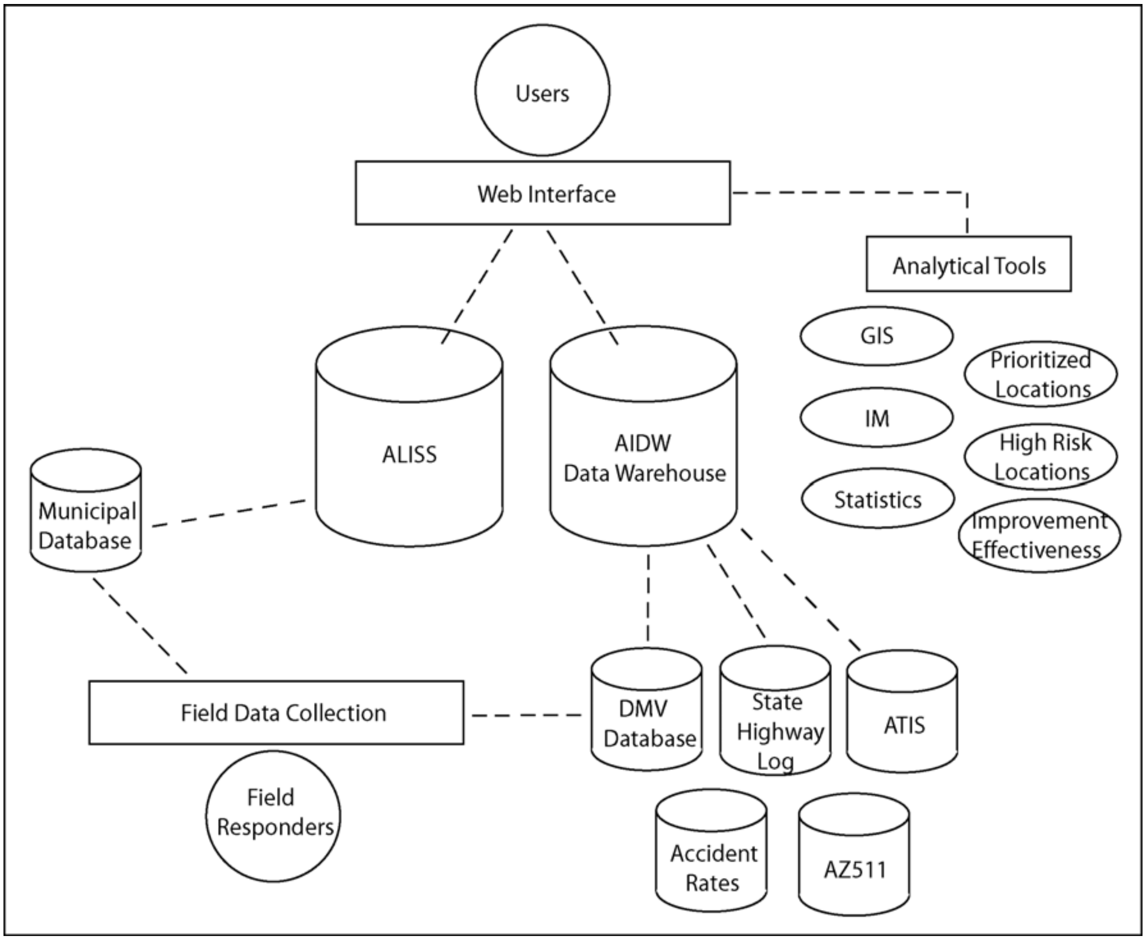

Figure 6. Overall Ideal System Design

component should then be developed to begin letting users become accustomed to the data that are available within the system and how they are integrated through the enterprise system. The data query and export functionality should come next to allow users to start using the site as a one-stop portal for information. The analytical components should follow, including frequently used analyses of prioritized accident locations and accident and severity rates. The help section for users should be created in conjunction with each of the installed components.

While the Web application is being developed, the electronic data-entry and electronic data transfer components can be developed, beginning with the implementation studies that detail the specific needs for each component. After the study for EDE, the data-capture application can be designed, built, and implemented. Once EDE is implemented, electronic data transfer can be implemented through workflows and exporting and importing routines.

Table 36 shows that estimated costing of the Overall System.

Table 36. Overall System Costing

Component	Cost
Electronic Data Entry	$280,000
Electronic Data Transfer	$250,000
GIS/GPS Integration	$200,000
MMUCC Standards	$10,000
Auto Data Populate	$265,000
Domains and Business Attributes.	$55,000
Crash Definition Standards	$185,000
New ALISS	$270,000
Integrate with State Highway System Log in AIDW	$10,000
Digital Crash Report Storage	$150,000
Advanced Stats, Charts, + Graphs	$95,000
GIS Tools	$45,000
Signalized Intersections	$25,000
Prioritized Crash Locations	$65,000
High Risk and Hazard Locations	$45,000
Improvement Effectiveness	$55,000
Crash and Severity Rates	$50,000
Street Names and Aliases	$35,000
Contract Release Dates	$30,000
Agency Data Sharing	$40,000
Intersection Magic (web)	$145,000
2^{nd} – 4^{th} , and Most Harmful Event	$80,000
Web Access Portal	$340,000
Current and Historical Reporting	$70,000
User Definer Export Format	$40,000
Total	**$2,835,000**

6. RECOMMENDATION AND IMPLEMENTATION STRATEGY

6.1 INTRODUCTION

The above recommendations represent an ideal implementation scenario, and ADOT should use it as a goal toward which to strive. Understanding that resources will be limited, the project team has created the following strategy that will deliver the most capability for the least funding while building toward the ultimate goal of the ideal system defined above. The steps and implementation strategy below should be developed and deployed with the long-term solution in mind.

6.2 STRATEGY

Step 1 – Creation of a new ALISS database

To accomplish the desires set forth in the previous portions of the study, a new database system must be devised to store and retrieve incident records (Table 37). Generating accident and severity rates, analyzing safety improvement effectiveness, and prioritizing accident locations by facility type all require that the ALISS and AIDW databases be linked. Unfortunately, the ALISS is neither documented nor customizable, preventing this link. Therefore, either funding needs to be applied to the ALISS to document it and make it customizable, or a new system needs to be developed.

The project team's recommendation is to create a new ALISS based upon a GIS system using an RDBMS and ArcSDE. This will provide the basis for a relationship between the AIDW and the ALISS while utilizing software capabilities already in place within ADOT. The new ALISS will need a new interface for data entry and minimal training for current data-entry staff. Once the database is created, the records in the ALISS will need migration from the old system to the new.

The new system should take advantage of MMUCC standards for data elements with the understanding that not all elements are currently collected in the field. In the future, as more agencies move toward electronic data entry, the ability to collect additional MMUCC elements may become available. The database should be designed to incorporate this possibility. The data elements of 2^{nd} – 4^{th}, and most harmful events should also be incorporated.

ADOT should try to maximize involvement from the Tribal governments in the new system by education and possibly an incentive program for participation.

The existing stored reports in the ALISS will need to be migrated to the new system. This functionality is very important to the crash data community as a whole, and the system would be taking a step backward if these reports were lost in the conversion.

Table 37. Step 1 New ALISS

Component	Cost
Database design	$35,000
Data migration	$30,000
Export routines	$15,000
Report generation	$45,000
Data entry interface	$30,000
Documentation	$5,000
Training	$10,000
Staff	$85,000
Total	**$255,000**

Step 2 – Integrate the new ALISS with the Current GIS Infrastructure and the data warehouse

ADOT GIS is undergoing a migration to a new geodatabase data structure for maintaining roadway information. This system is linear-referenced with dynamic segmentation and is capable of storing a variety of facility information in the relational database scheme. The project team recommends integrating the ALISS with the new GIS roadways database and the AIDW (Table 38). This will provide all facility information in a format that can be analyzed with the new ALISS.

Table 38. Step 2 ALISS and Transportation GIS Integration

Component	Cost
Automation routines	$20,000
Documentation	$5,000
Total	**$25,000**

Note: Steps one and two are the most important aspects of this implementation plan and should be performed concurrently to maximize interoperability and minimize cost.

Step 3 – Create Electronic Data Transfer (EDT) Routines

ADOT is duplicating a significant amount of effort by not accepting electronic transfer of incident records. Several municipalities type incident records into a database system within their offices, just to turn around and print a hardcopy that is sent to ADOT for re-keying into the ALISS. The project team recommends that ADOT accept EDT and create import routines and workflows to support this initiative (Table 39). This will involve a study to determine all the possible data export formats that will identify the systems that the various agencies use for their incident records. More than likely, only five or six different systems are in use, and ADOT should be able to create the import routines with minimal effort. Also aiding this is that each record should contain the same data elements, minimizing the complexity of creating routines.

Table 39. Step 3 Electronic Data Transfer

Component	Cost
Implementation study	$25,000
Import routines	$20,000
Workflows	$20,000
Documentation	$5,000
Staff @ 10 hours/wk	$20,000
Total	**$90,000**

Step 4 – Create Web Access to Integrated Databases for Query and Download (ArcIMS)

Staff resources are required to distribute ALISS data to users both within and outside ADOT. This expense can be eliminated by utilizing existing software within ADOT GIS. ArcIMS is a Web-based application that allows for display, query, and download of GIS data through the Internet at a user's discretion. With the ALISS being integrated with the AIDW and the transportation GIS database, users can enter through the ArcIMS Website to access data (Table 40). Basic GIS functionality is inherently available to all users who have access to the Website. This will also provide live access to the ALISS, ensuring that users get up-to-date information for their analyses. ArcIMS can be designed to only display and export information that is not sensitive, or a security system can be implemented to grant or deny users access to sensitive data.

Table 40. Step 4 Web Access for Data Query and Download

Component	Cost
ArcIMS website	$30,000
Data query and download	$30,000
Security scheme	$10,000
Documentation	$5,000
Total	**$75,000**

Step 5 – Accident and Severity Rates Database

With the linkage of the ALISS, AIDW, and transportation GIS databases, accident and severity rates can be calculated for facility types by numerous factors, including vehicle type, driver's age and gender, weather conditions, and geography (Table 41). These rates should be incorporated into a database for all to use. This database can be created without staff involvement, with the exception of typical administration routines. Once the database is built, updating the rate values can be automated. These calculations are relatively simple within a GIS and can be provided through the ArcIMS website with minimal funding. A small study should be undertaken to decide which rate calculations will be made available, including by time and geography (i.e. weekly, monthly, yearly by county, ZIP code, region, by facility, type, age, weather, etc.). The study will drive the database design, the number of execution statements required, and the frequency of the rate updates. The rates will then be tied to the appropriate transportation GIS features for inclusion into the overall system for users to analyze. The Maricopa Association of Governments (MAG) is currently researching this database's feasibility, and the progress of this study should be monitored.

Table 41. Step 5 Accident and Severity Rates Data

Component	Cost
Needs study	$15,000
Database design	$15,000
Automation routines	$25,000
Documentation	$5,000
Total	**$60,000**

Step 6 – Additional data collection efforts

All analytical capabilities start with good data resources. The collection of signalized intersections data, contract release dates, and safety improvements can grant users analytical capabilities that they currently do not have. Most of these data resources should already be maintained through various agencies, including ADOT, and need only to be found and integrated into the GIS system (Table 42). Some data will be more resource-intensive to integrate than other, but the level of effort cannot be quantified until these resources can be found and analyzed.

Table 42. Step 6 Additional Data Collection Efforts

Component	Cost
Database design (All)	$15,000
Data mining	$5,000-$25,000/ea
Database population	$5,000-$25,000/ea
Documentation	$5,000
Total	**> $30,000 and < $70,000**

Step 7 – Electronic Data Entry

It would be optimal for the state to embrace electronic data entry for all incident records (Table 43). This may not be feasible due to financial limitations, but ADOT should promote its use whenever possible in the hopes that eventually this will become a reality.

Table 43. Step 7 Electronic Data Entry

Component	Cost
Hardware inventory	$20,000
Hardware (computer)	$2,000/ea
Hardware (Personal Digital Assistant)	$750/ea
Custom data entry and storage software	$65,000
Domains & business attribute rules	$20,000
Export routines	$25,000
Installation	$100,000
Training	$75,000
Total (not including hardware)	**$305,000**

6.3 OVERALL PRIORITIZED IMPLEMENTATION

Below is a prioritized implementation strategy for developing the ideal system design. The strategy is the recommendation of the project team and should be used as a roadmap to follow in creating the ideal system, one component at a time. This is a listing of the items mentioned in the previous portions of this document and are displayed in a prioritized manner. For a detailed description of each component, please refer to the Technical Memorandum where each component is discussed in detail.

Strategy Steps

1. Create new ALISS Database Utilizing Domains, Business Attributes, MMUCC, and Harmful Events.
2. Integrate ALISS with ATIS and AIDW.
3. Create Electronic Data Transfer Routines.
4. Accident and Severity Rates Database (From Regional).
5. Additional Data Collection – Signalized Intersections.
6. Additional Data Collection – Safety Improvements.
7. Additional Data Collection – Road Open Dates.
8. Additional Data Collection – Street Names and Aliases.
9. Promote Electronic Data Entry.

10. Create and Educate on Crash Definition Standards.
11. Current, Historical, and Custom Reporting.
12. Make ADOT’s AIDW available over Internet.
13. Create Improvement Effectiveness Analysis Tool.
14. Create Prioritized Location Analysis Tool.
15. Create Advanced Statistical, Charting, and Graphing Tools.
16. Integrate Enterprise Databases for Automatic Data Population from Databases such as DMV.
17. Create High Risk and Hazard Location Analysis Tool.
18. Integrate Intersection Magic Internet Capability.
19. Create User Defined Export Format Capabilities.
20. GIS/GPS Field Unit Integration for Data Collection.

Appendix A. SURVEY QUESTIONS

1. Please enter your state.

2. Please enter your name (Last, First).

3. Please enter your job title.

4. How long have you worked with crash data systems?

5. When was your crash system developed? Enter date in M/D/YYYY format.

6. Did you switch from another system?

7. If answer to Question 6 is yes, please provide a brief description.

8. Were other states' crash data systems analyzed during or prior to development of your system?

9. If answer to Question 8 is yes, please select which states' systems were used for modeling.

10. How long did it take to implement the current crash data system?

11. Which system are you currently using to analyze your crash data? Please select one. If your system is not listed, as a choice please provide a brief description.
    - HSA (Highway Safety Analysis Software)
    - AIMS (Accident Information Management System)
    - SAVER (Safety, Analysis, Visualization, and Exploration Resource)
    - Polaris
    - Intersection Magic
    - Traffic Collision Database
    - Other
    - Custom Designed System

12. If the answer to Question 11 is “other” or “Customized”, Please briefly describe your "Customized" or "Other" analysis system here.

13. Which system are you currently using to store your crash data? Please select one. If your system is not listed as a choice please provide a brief description.
    - Same as above
    - TRASER (TRAffic SERvices Microcomputer System)
    - Access-ALAS (Accident Location and Analysis System)
    - ARS (Accident Records System)
    - Custom Designed System
    - Other

14. If the answer to Question 13 is “other” or “Customized”, Please enter your "Other" or "Customized" storage system description here.

15. How is data entered into the system?
    - Entered by hand from crash reports.
    - Entered electronically by crash responders.
    - Using TRACS (Traffic and Criminal Software)
    - Other

16. If you chose "Other" in Question 15, please provide a brief description here.

17. How is data served out to the clients?
    - Local interface.
    - Web-based interface.
    - Database queries.
    - Document management system of scanned documents.
    - CDROM
    - FTP Server
    - Other

18. If data is served by "Other" please provide a brief description.

19. Is your system for accessing and entering data the same system or different systems?
    - Same
    - Different

20. If the answer to Question 19 is different please provide a brief description here.

21. Who are the primary users of the data?
    - High level decision makers
    - Traffic Engineers
    - District/Division Office Staff
    - Law Enforcement
    - The General Public
    - State Agencies
    - Municipalities
    - Counties
    - FHWA
    - Councils of Government
    - Other

22. If "Other" primary user is selected in Question 21, please provide a brief description.

23. What training is available for each group? Please briefly describe.

24. What other systems are linked to crash event records?
    - DMV
    - EMS
    - Hospitals
    - DOT Inventory
    - Traffic and Roadway Data
    - Law Enforcement
    - Insurance
    - Other
    - None

25. If "Other" data system is selected in the above question, Please provide a brief description.

26. How are different types of crash analysis data output acquired?

	Manual	Automatic	Insufficient
Facility types: 2 Lane, 4 Lane, 5 Lane, undivided, divided, controlled access			
Accident Conditions Reports / Summaries - Weather, Lighting, Road Surface, Time of Day, Day of Week, etc.USDOT (United States Department of Transportation)			
Crash Event Reports / Summaries – Collision Cause, Collision Type, Vehicle Type, Object Type, Injury Type, Severity, Directional, Location, etc.			
Hot Spots / Corridors			
Crash Rates – Intersection / Segments			
Collision Diagrams – Intersection / Segments			
Critical Rate Comparisons			
Before / After Improvement Comparisons, Cost / Benefit			

27. Is the output module customizable?

28. Which type of operating system do you currently use? Please select one, if one is not listed as a choice please provide a brief description.
    - Windows NT
    - Windows 2000
    - Windows Xp

- Unix
- Linux
- Macintosh OS
- Sun Solaris
- Hp-UX
- DEC-Alpha
- Other

29. If "other" is selected in Question 28, please enter your operating system description here.

30. Please describe which type of database management system you use.

31. Which type of GIS software are you using? Please select one. If yours is not listed as a choice, please describe in brief.
    - ESRI
    - Intergraph
    - AutoCAD Map 2000
    - MapInfo
    - Microstation Geographics
    - SmallWorld
    - None
    - Other

32. Please enter your GIS software description here.

33. Is the crash analysis output used in GIS?

34. If "yes" is answered in Question 33, please give a brief description.

35. Which type of CAD software are you using? Please select one, if one is not listed as a choice please describe in brief.
    - Auto CAD
    - Microstation
    - Intergraph
    - None
    - Other

36. Please enter your CAD software description here.

37. Which organizations do you coordinate with or report to?
    - FHWA (Federal Highway Administration)
    - NHTSA (National Highway Traffic Safety Administration)
    - Local Government
    - Other

38. What standards do they mandate that you must adhere to? Please provide a brief description.

39. Are there any groups or areas that are not currently using or participating in the crash data system?

    - Universities
    - Airports
    - Military bases
    - Native American Reservations
    - National or State Parks
    - Other

40. If "Other" is selected in Question 39, please list them.

41. Please briefly describe the added benefit of their participation.

42. Do the state or local municipalities utilize real-time crash information located with GPS to offer drivers travel warnings?

43. If the answer to Question 42 is yes, please briefly describe this function.

44. What things would you have done differently in the development and implementation phases of your crash data system?

45. What aspect of the current system is the most beneficial?

46. What additional functionality would you like to have enabled?

47. If any documents or publications concerning your crash data and/or analysis system are available online please provide the address below.