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A Feasibility Study for Arizona's Roadway Safety Management Process Using the Highway Safety Manual and *SafetyAnalyst*

Arizona Department of Transportation Research Center

ADOT

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16. Abstract

To enable implementation of the American Association of State Highway Transportation (AASHTO) Highway Safety Manual using *SaftetyAnalyst* (an AASHTOWare software product), the Arizona Department of Transportation (ADOT) studied the data assessment and integration requirements. The research identified the data needs for the *SafetyAnalyst* software, assessed the quality of data available, addressed all "required element" data gaps, and prepared the requirements for data input and post-processing output for presentation and interpretation. This research provides an overview of critical data needs and system requirements for ADOT's deployment of *SafetyAnalyst*, identifies gaps between existing and desired conditions needed for successful software implementation, sets priorities for filling these data gaps, recommends a strategy for integrating the software into standard ADOT practices, and recommends a technology strategy to support a phased implementation.

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SafetyAnalyst software, Highway Safety Manual, HSM, network screening, roadway safety management, safety data

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
^oF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^oC
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
^oC	Celsius	1.8C+32	Fahrenheit	^oF
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	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.
(Revised March 2003)

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List of Acronyms

AADT ....annual average daily traffic
AASHTO.........................American Association of State Highway and Transportation Officials
ADOT ....Arizona Department of Transportation
ADT...............................average daily traffic
AIDW ....Arizona Information Data Warehouse
ALISS.............................Accident Location Information Surveillance System
ATIS ....Arizona Transportation Information System
C-D................................collector-distributor
CMF ....crash modification factor
COG ....Council of Governments
CPM..............................Certification of Public Road Mileage
CSV ....comma-separated values
DBMS............................Database Management System
Dfo................................fixed-object density
DOT ....department of transportation
EB ....Empirical Bayes
EPDO ....Equivalent Property Damage Only
ER ....entity relationship
ETL................................exchange transfer load
FAQ...............................frequently asked question
FHWA ....Federal Highway Administration
FTP................................file transfer protocol
GB.................................gigabyte
GIS ....Geographic Information System
HPMS............................Highway Performance Monitoring System
HSIP ....Highway Safety Improvement Program
HSIS ....Highway Safety Information System
HSM..............................Highway Safety Manual
HTML............................HyperText Markup Language
IHSDM ....Interactive Highway System Design Model
ID ....identification
IT ....information technology
ITG................................Information Technology Group
JDBC ....Java Database Connectivity
JRE ....Java Runtime Environment
L/DCR ....Location/Design Concept Report
LRM ....linear referencing method
LRS................................linear referencing system
MAP-21 ....Moving Ahead for Progress in the 21st Century Act

MB .... megabyte
MPD.............................. Multimodal Planning Division
MPO .... Metropolitan Planning Organization
ODOT............................ Ohio Department of Transportation
Ofo .... fixed-object offset
P2P .... Planning to Programming
PA .... project assessment
PC .... personal computer
PDF .... Portable Document Format
RCI .... Roadway Characteristics Inventory
RDBMS .... Relational Database Management Server
ROI................................ return on investment
RTF .... rich text format
SA .... SafetyAnalyst
SDM.............................. Safety Data Mart
SPF................................ safety performance function
SQL .... Structured Query Language
SR .... State Route
TEG .... Traffic Engineering Group
TRS .... Traffic Records Section
TSS................................ Traffic Safety System
txt .... text file
WSDOT .... Washington State Department of Transportation

EXECUTIVE SUMMARY

The 2012 Moving Ahead for Progress in the 21st Century Act (MAP-21) increased funding for state Highway Safety Improvement Programs. For states to efficiently and effectively allocate these funds, it is necessary to identify which intersections or roadway segments would respond to safety improvements, to understand crash characteristics and contributing factors, and to identify potential countermeasures for reducing crash frequency and severity.

In 2010, the American Association of State Highway Transportation Officials (AASHTO) published the first edition Highway Safety Manual (HSM), which includes a number of quantitative analysis tools for evaluating safety performance in the transportation system. One section of the HSM, Part B, Roadway Safety Management Process, provides methods for identifying intersections and roadway segments that have the potential for responding to safety improvements.

SafetyAnalyst software (an AASHTOWare product) makes it possible for a state transportation department to use methods from the HSM and to automate the process of identifying intersections or roadway segments that may respond to safety improvements, identifying potential improvements, conducting benefit-cost analyses, and prioritizing projects for safety investments. The software delivers analyses that are reliable, that are repeatable, and that assist safety project prioritization. Deploying *SafetyAnalyst* requires that statewide crash, roadway network, and traffic volume data be integrated into the specific database and data organization required to run the software. The major effort in deploying *SafetyAnalyst* is integrating these different databases into a single database that meets specific requirements.

The Arizona Department of Transportation's (ADOT) objectives for this research were to identify the data needs for the software, assess the quality of existing state data, address all data gaps, list the requirements for inputting data and postprocessing *SafetyAnalyst*'s output, and provide recommendations for deploying the software. The research addressed the combined concerns of staffing, process, and future applications, as well as the data and technology requirements.

Recommendations

Concerning staffing, process, and future applications, it is recommended that ADOT commit staff time from several units—Information Technology Group (ITG), Traffic Safety Section (TSS), Traffic Records Section (TRS), Multimodal Planning Division (MPD), and Traffic Engineering Group (TEG)—to develop and deploy the model. The team could comprise all ADOT staff or could include a contractor; however, knowledge of ADOT database content and structures is required.

The ADOT team, collaborating to complete the data mapping, will need detailed knowledge of Arizona's crash, roadway, and traffic volume databases; safety expertise; and traffic engineering expertise. It is estimated that it would take this team six months to a year to implement the first phase of the software, assuming regular and frequent meetings, perhaps on a weekly basis, to review and confirm progress, data needs, and data assumptions. The team would run the program initially for the network screening using available data; address errors/issues; and verify the outcome.

An initial pilot deployment is recommended, with a long-term commitment to fully deploy the software system wide. Over the long term, this will require the ADOT team to meet periodically to manage the data system, plan for and deploy the different phases of the model, validate the model, apply the model, and develop and provide training on the model, as needed.

From a data and technology perspective, the research supported recommendations for developing and distributing the model (i.e., enterprise deployment); populating the database and completing the data mapping; distributing and maintaining the software within ADOT; and implementing information technology (IT) enhancements to develop the model. The recommendations relate to hardware and software requirements and configurations; data storage needs; organization of people, systems, and data required to deploy *SafetyAnalyst*; filling data gaps; data distribution; and a technology implementation strategy.

CHAPTER 1. INTRODUCTION

The Arizona Department of Transportation (ADOT) Highway Safety Improvement Program (HSIP) focuses on locating and addressing potential safety concerns on State Highway Systems. There are three components to a successful HSIP: Planning, Implementation, and Evaluation (ADOT 2010, page 13). Planning for highway safety involves identifying sites with potential for safety improvement, studying the sites and selecting cost-effective countermeasures, and prioritizing the sites to achieve the most cost-effective safety investment program. While state safety planners and engineers have been conducting these analyses for many years, states have recently been required by federal transportation funding legislation to conduct analyses for all public roads, and the analytical tools available to conduct these analyses have changed. Statistical methods for identifying sites with potential for safety improvement have improved and provide results that remain consistent from year to year, and software tools have been developed to deploy these methods comprehensively.

One such tool is the AASHTOWare licensed product *SafetyAnalyst*. Developed through a Federal Highway Administration (FHWA)-pooled fund study, *SafetyAnalyst* is a software tool for comprehensive roadway safety management analysis. The *SafetyAnalyst* software brings many advantages to a state department of transportation (DOT). The quantitative network screening methods in the software are considered state-of-the-practice and are consistent with, though not entirely the same as, the network screening methods described in the first edition of the American Association of State Highway and Transportation Officials (AASHTO) Highway Safety Manual (HSM). The software automates tedious processes to apply advanced network screening methods at a statewide level (e.g., identifying and segmenting homogenous roadway segments); provides guidance for diagnosing issues and selecting countermeasures; and automates benefit-cost and project prioritization processes for large networks.

Developing and deploying the software requires significant effort from Information Technology (IT), planning, traffic engineering, and safety staff to map data from existing state databases into the software, and to identify and prioritize data needed to fill gaps that might prevent the software from functioning properly. Toward this end, the objectives of this project were to identify the data needs for *SafetyAnalyst* software, assess the quality of existing state data, address all data gaps, and identify requirements for inputting data and post-processing *SafetyAnalyst*'s output for presentation. This research developed a path for ADOT to identify the labor, materials, and other resources necessary to successfully implement *SafetyAnalyst* as a tool for safety planning in Arizona transportation projects.

To accomplish these objectives, the research team:

- Researched and evaluated *SafetyAnalyst* data requirements and success stories of applying *SafetyAnalyst* at Washington State DOT and Ohio DOT.
- Evaluated existing ADOT data sources, technologies, and intentions for applying *SafetyAnalyst.*
- Conducted a pilot application of *SafetyAnalyst* on a small portion of the ADOT system.
- Recommended approaches to filling data gaps and implementing the software.
- Recommended data integration and management for ADOT's approved technology stack. (A technology stack is a suite of subcomponents or layers needed to create a complete tool.)

This report is organized into chapters that address each element of the research:

- Chapter 2 – An overview of the critical data and systems requirements for a successful *SafetyAnalyst* implementation.
- Chapter 3 – An overview of the state of the practice on *SafetyAnalyst* development and implementation at Washington and Ohio Departments of Transportation.
- Chapter 4 – Documentation of ADOT's desires for integrating *SafetyAnalyst* and the availability of agency data systems, preliminary gaps and resources that could satisfy *SafetyAnalyst's* data requirements.
- Chapter 5 – Detailed discussion of gaps between existing and desired conditions needed for successful implementation of the software, as well as recommendations on how to fill these gaps.
- Chapter 6 – Recommendations for integrating *SafetyAnalyst* into standard business practices at ADOT.
- Chapter 7 – Recommendations for a technology implementation strategy to support *SafetyAnalyst* implementation.
- Chapter 8 – Recommendations and conclusions for this project.

CHAPTER 2. DATA REQUIREMENTS FOR HSM AND *SAFETYANALYST*

This chapter summarizes the critical data and systems requirements for successful *SafetyAnalyst* implementation. To accomplish this task, the research team researched, reviewed, and summarized HSM and *SafetyAnalyst* data and IT needs using existing HSM and *SafetyAnalyst* documentation.

Overview of *SafetyAnalyst*

SafetyAnalyst is a software package available through AASHTO. It can be used by transportation agencies to identify safety improvement needs and guide systemwide programming of site-specific safety improvements through the general safety management process. *SafetyAnalyst* deploys Part B, Roadway Safety Management Process, of the AASHTO HSM. Part B of the HSM provides methods for identifying intersections and roadway segments that have the potential for responding to safety improvements. *SafetyAnalyst* makes it possible for a state to automate the evaluation process and use the most advanced methods from the HSM to identify intersections or segments that may respond to safety improvements, identify potential improvements, conduct benefit-cost analyses, and prioritize projects for safety investments.

There are four modules in the *SafetyAnalyst* software:

- Module 1 – Network Screening. This module allows users to review the entire roadway network and identify sites with potential for safety improvements.
- Module 2 – Diagnosis and Countermeasure Selection. This module helps users diagnose safety problems at a specific site and select appropriate countermeasures.
- Module 3 – Economic Appraisal and Priority Ranking. This module allows users to conduct an economic analysis of a specific countermeasure or several alternative countermeasures for a specific site. The priority ranking functionality ranks countermeasures by the benefit and cost estimates determined by the economic appraisal.
- Module 4 – Countermeasure Evaluation. This module helps users estimate the safety effect of countermeasures implemented at a specific site.

SafetyAnalyst Data Requirements

SafetyAnalyst has two tiers of data requirements: 1) required minimum data and 2) recommended additional data. The required minimum data are the datasets and attributes that must be present in the appropriate format and loaded into the *SafetyAnalyst* database for the software to operate. These required datasets include Roadway Segments, Intersections, Ramps, and Crashes. The minimum attributes for each dataset are listed in Figure 1.

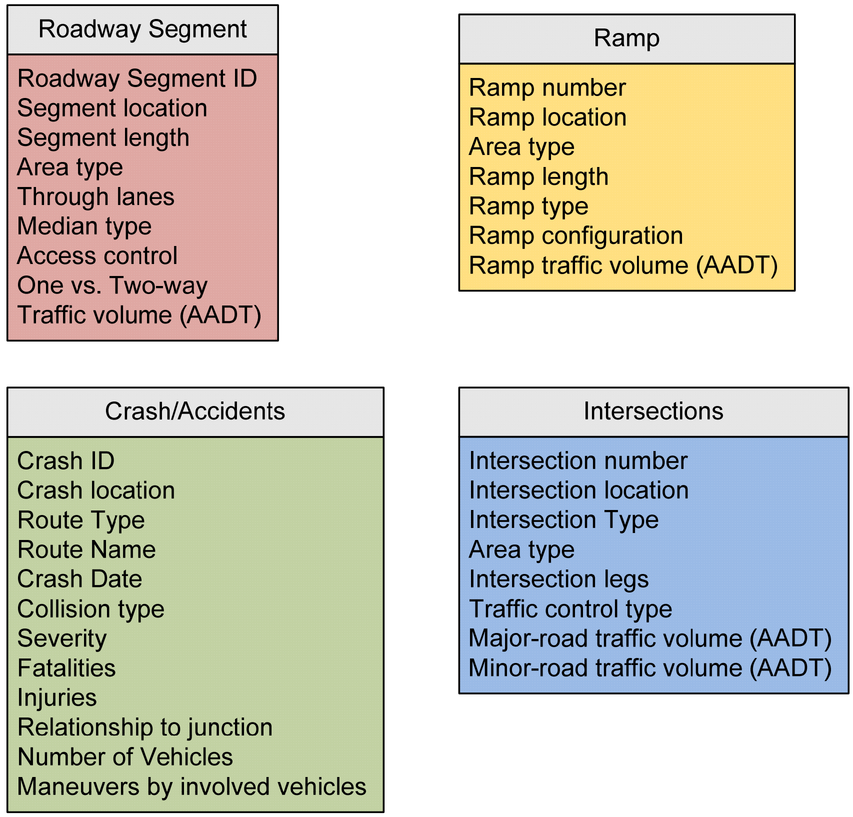


Figure 1. Minimum Attributes by Dataset

Beyond the required minimum data, the *SafetyAnalyst* guidance documents suggest that the full database schema should be implemented to take full advantage of the network screening tools and other modules.The full *SafetyAnalyst* schema adds a significant volume of attribute data and introduces some complex relationships between attribute tables. For example, the minimum schema requires the presence of an intersection and the traffic volumes at each leg of the intersection. The full recommended schema for *SafetyAnalyst* input data is presented in Figure 2.

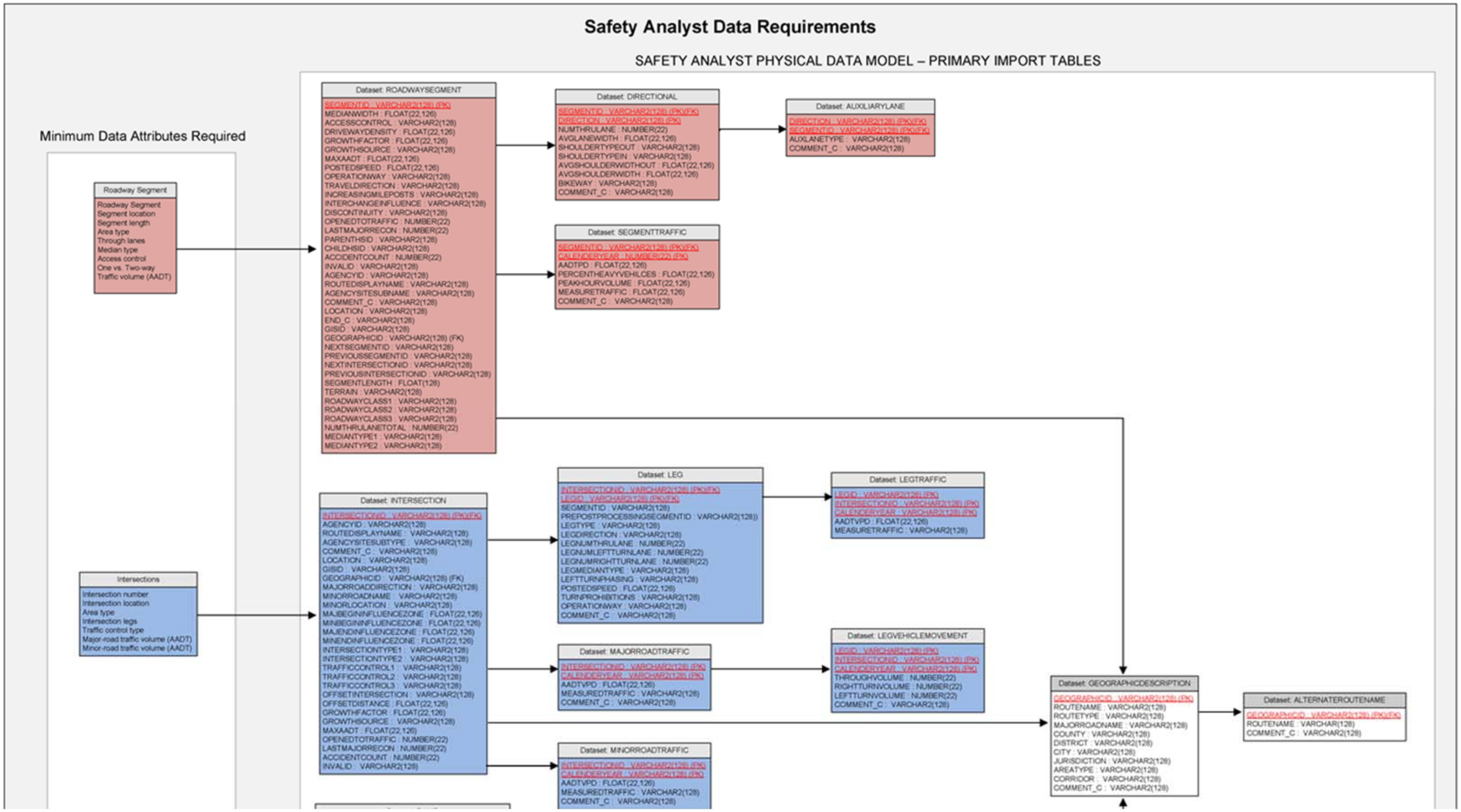


Figure 2. *SafetyAnalyst* Database Schema

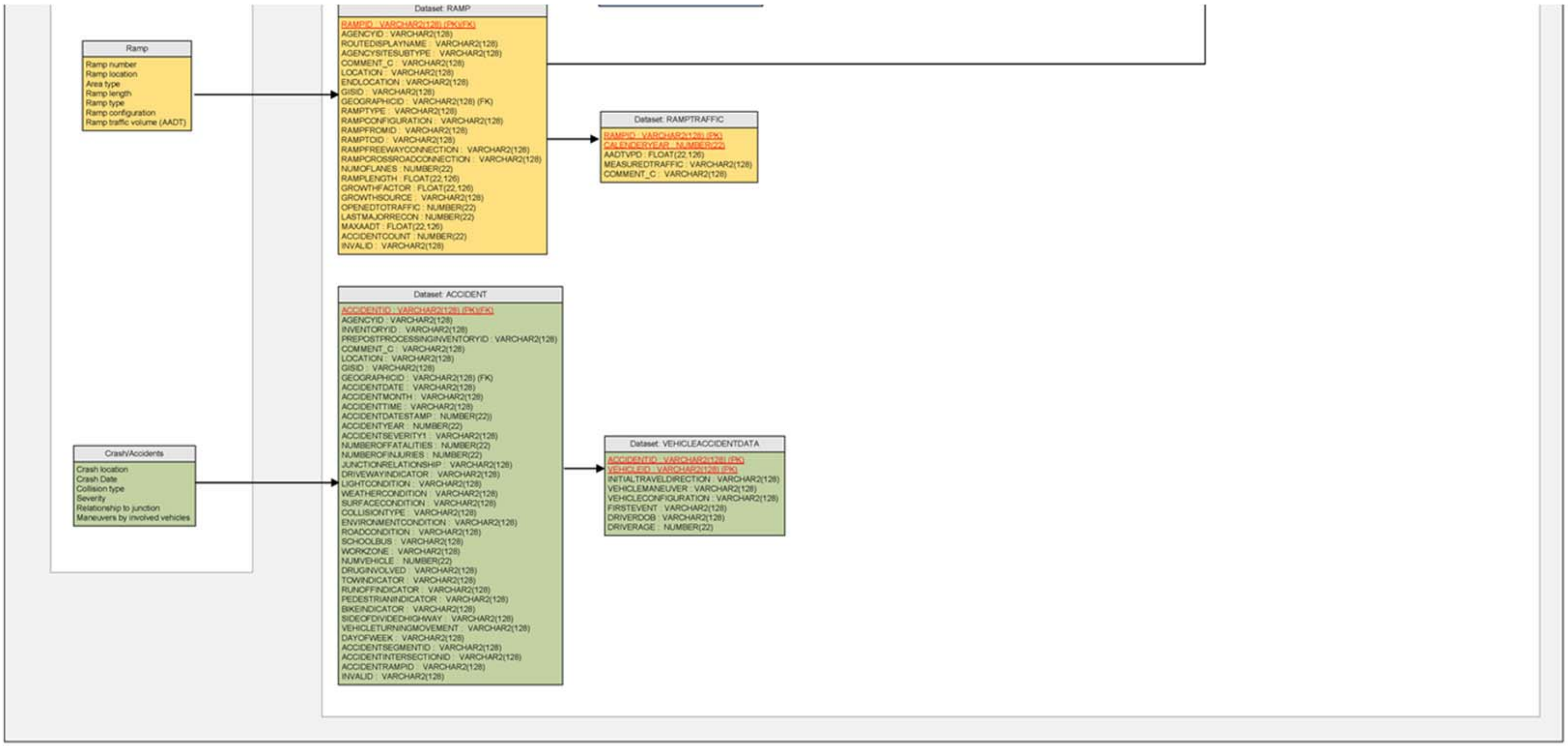


Figure 2. ***SafetyAnalyst*** **Database Schema (Continued)**

The boxes in the ER diagram represent data tables in the *SafetyAnalyst* database. Within each box is a listing of attributes for that data table and the data type and size requirements for the attribute value. For example, ACCIDENTID: VARCHAR2 (128) represents an attribute for Accident ID, which can be a mix of numbers and letters up to 128 characters long. Attributes listed in red must be unique identifiers that then establish a primary key/foreign key relationship to another attribute table within the schema.

SafetyAnalyst System Requirements

The *SafetyAnalyst* software package must be installed on a computer that allows user access to the *SafetyAnalyst* application and database. *SafetyAnalyst* supports two configurations for implementation: 1) stand-alone workstation implementation, and 2) enterprise implementation. The stand-alone configuration is intended for individual or small group use, while the enterprise configuration is intended for multiuser organizations. Both configurations allow for full utilization of the *SafetyAnalyst* product.

The stand-alone configuration requires a Personal Computer (PC) workstation with the minimum specifications shown in Table 1.

Table 1. Minimum Hardware Specifications for a Stand-Alone Work Station

	Small Agency	Large Agency
Machine	x86 (32-bit)	x86-64 (64-bit)
CPU	Operating system dependent	Operating system dependent
Memory	1 GB	2 GB
Video	1024 x 768, 16-bit color	1024 x 768, 16-bit color
Mouse	Microsoft or compatible	Microsoft or compatible
Hard Disk	200 MB	200 MB

Given the volume of crash records available to ADOT and the complexity of the roadway network, the research team recommends that ADOT use the “Large Agency” minimum specifications for any stand-alone configuration.

The *SafetyAnalyst* Administration Tool Manual, however, recommends that a stand-alone configuration use a PC workstation with the specifications shown in Table 2.

Table 2. Hardware Specifications for a Stand-Alone Work Station Installed with Safety Analyst

	Small Agency	**Large Agency**
Machine	x86 (32-bit)	x86-64 (64-bit)
CPU	Operating system dependent	Operating system dependent
Memory	2 GB	8 GB
Video	1280 x 1024, 32-bit color	1280 x 1024, 32-bit color
Mouse	Microsoft or compatible	Microsoft or compatible
Hard Disk	20 GB	20 GB

In addition to the hardware requirements for a stand-alone configuration, *SafetyAnalyst* requires the software shown in Table 3.

Table 3. *SafetyAnalyst* Software Requirements

Operating System	Microsoft Windows XP (32-bit or 64-bit) Windows Vista (32-bit or 64-bit) Windows 7 (32-bit or 64-bit) A Linux version of *SafetyAnalyst* is available on request.
Browser	HTML browser, PDF viewer, or RTF viewer required; CSV-capable spreadsheet program recommended.

The *SafetyAnalyst* stand-alone configuration requires the use of a Java Database Connectivity (JDBC)-compliant database. Therefore, only JAVA databases or Apache Derby are supported.

For an enterprise deployment of *SafetyAnalyst*, an additional hardware and software configuration is required. An enterprise deployment extends the *SafetyAnalyst* application to many users and improves the overall performance of the system and analysis. The enterprise deployment still requires an individual user to have a workstation meeting the minimum requirements shown above. The enterprise deployment requires that the workstation be connected to the agency's network and that the database server meet the specifications shown in Table 4.

Table 4. Additional Hardware and Software Configuration Requirements for an Enterprise Deployment

Hard Disk	20 GB
Network	100 Mbit/s minimum, 1 Gbit/s recommended
Database Management System (DBMS)	Any hardware, operating system, and an SQL-compliant DBMS that supports the Java Database Connectivity (JDBC) API[a]

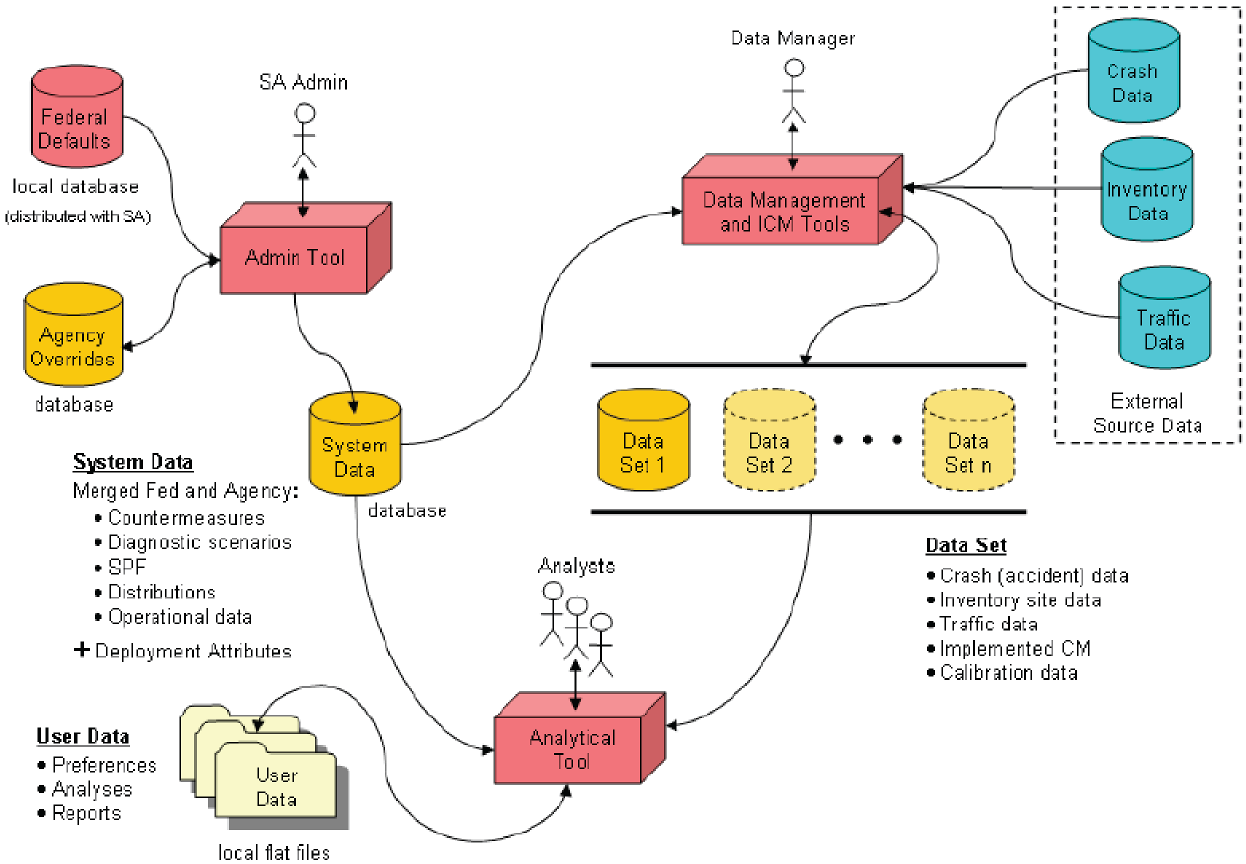
[a] Fully tested DBMS include Oracle, Microsoft SQL Server, and Apache Derby. Minimal testing has been conducted on MySQL and Sybase DBMS.

ADOT's standard Microsoft SQL Server is a supported Relational Database Management Server (RDBMS) for *SafetyAnalyst*.

Other considerations for *SafetyAnalyst* hardware and software configurations are as follows:

- CPU and memory requirements vary by operating system. For Microsoft operating systems, the minimum requirements recommended for the selected operating system are sufficient to support *SafetyAnalyst* in a minimum (stand-alone) configuration.
- *SafetyAnalyst* database is limited to 1 GB on 32-bit systems. For large datasets (in excess of 70,000 sites or 1 million crash records), a 64-bit operating system with 2 GB or more of memory may be required to perform data management, or to perform single network screening analysis on all sites in the dataset.
- *SafetyAnalyst* is implemented in the Java programming language. It will run on any platform with a Version 6 Java runtime environment (JRE). The Version 6 32-bit JRE is packaged with the *SafetyAnalyst* installers. A separate Version 6 64-bit JRE is also available.
- Although not officially supported, *SafetyAnalyst* may function on operating systems that are no longer supported by Microsoft (e.g., Windows 2000 Professional).
- Data storage requirements depend on the size of the inventory, traffic, and crash data. For example, a near-production dataset of 25,000 roadway segments, 46,000 intersections, 1.4 million crashes, and nine years of traffic data requires less than 1.5 GB of disk space for a local (Apache Derby) database.

Figure 3, reproduced from the *SafetyAnalyst* manuals (FHWA 2009a–2009d), provides an overview of the *SafetyAnalyst* systems architecture (including users, data, and tools).



Source: FHWA 2009d

Figure 3. *SafetyAnalyst* Data Model

Highway Safety Manual Data Requirements

The HSM (AASHTO 2010, 2014) presents a variety of analysis methodologies that can be used in the safety management process. The HSM is organized into the following four parts:

- Part A – Introduction, Human Factors, and Fundamentals
- Part B – Roadway Safety Management Process
- Part C – Predictive Method
- Part D – Crash Modification Factors

In general, HSM methods require crash, facility, and traffic volume data:

- **Crash data.** HSM applications typically require the following crash data elements: crash location (milepost/log mile/coordinate); date and time; severity level (fatal/injury/ property damage only); collision type; and basic information about the roadway, vehicles, and people involved.
- **Facility data**. Facilities can be either roadway segments or intersections.

- Roadway segments. Facility characteristics for roadway segments generally include area type (e.g., urban/suburban, rural); site length; roadway cross section; added lanes; roadway horizontal and vertical alignment; driveway type (e.g., major or minor industrial/institutional, major or minor commercial, major or minor residential); density; roadside conditions; and lighting.
- Intersections. Facility characteristics for intersections generally include intersection configuration, type of traffic control, turn lanes, intersection angle, sight distance, enforcement devices, terrain, and lighting.

- **Traffic volume data**. For roadway segments, the annual average daily traffic (AADT) volumes for the road in question are needed; for intersections, the average daily traffic (ADT) volumes of intersecting roads (major and minor roads) are needed. In some cases, additional volume data, such as pedestrian crossing counts or turning movement volumes, may be necessary.

The availability of data influences the HSM methods that can be applied. In addition, the more rigorous HSM methods require statistical analysis to develop either local safety performance functions or local calibration factors. This section identifies the data necessary for Part B, Roadway Safety Management Process and Part C, Predictive Method.

Part B – Roadway Safety Management Process

Part B of the HSM, the Roadway Safety Management Process, includes chapters on Network Screening, Diagnosis, Countermeasure Selection, Economic Appraisal, Project Prioritization, and Safety Effectiveness Evaluation. Network Screening and Economic Appraisal are the most data-intensive chapters in Part B. Data requirements for these chapters are presented below (Dixon et al. 2011).

Network Screening. Network screening is the process of identifying and ranking sites where countermeasures are likely to be effective in reducing crash frequency. The HSM identifies 13 performance measures that can be used for network screening; the data requirements vary depending on the performance measure(s) being used. Table 5 summarizes the data requirements of the 13 performance measures included in the HSM. All 13 methods require crash data and roadway information for categorization. Some of the methods also require traffic volumes or a calibrated safety performance function (SPF) with an overdispersion parameter.

Table 5. Network Screening Performance Measures Data Needs

Performance Measures	Crash Data	Roadway Information for Categorization	Traffic Volume[a]	Calibrated Safety Performance Function and Overdispersion Parameter	Other
Average Crash Frequency	X	X			
Crash Rate	X	X	X		
Equivalent Property Damage Only (EPDO) Average Crash Frequency	X	X			EPDO Weighting Factors
Relative Severity Index	X	X			Relative Severity Indices
Critical Crash Rate	X	X	X		
Excess Predicted Average Crash Frequency Using Method of Moments[b]	X	X	X		
Level of Service of Safety	X	X	X	X	
Excess Predicted Average Crash Frequency Using Safety Performance Functions (SPF)	X	X	X	X	
Probability of Specific Crash Types Exceeding Threshold Proportion	X	X			
Excess Proportion of Specific Crash Types	X	X			
Expected Average Crash Frequency with Empirical Bayes (EB) Adjustment	X	X	X	X	
EPDO Average Crash Frequency with EB Adjustment	X	X	X	X	EPDO Weighting Factors
Excess Expected Average Crash Frequency with EB Adjustment	X	X	X	X	

Source: AASHTO 2010. Highway Safety Manual, Volume I. Table 4-1, Summary of Data Needs for Performance Measures.

[a] Traffic volumes could be AADT, ADT, or peak-hour volumes.

[b] The Method of Moments consists of adjusting a site's observed crash frequency according to the variance in the crash data and average crash counts for the site's reference population. Traffic volume is needed to apply Method of Moments to establish the reference populations by ranges of traffic volumes, as well as site geometric characteristics.

In a network screening process, the selected performance measure is applied to all sites under consideration. The screening methods depend on the type of facility:

- Segments (e.g., roadway segments or ramps) are screened by using either sliding window or peak-searching methods. The simple ranking method also can be applied to segments; however, unlike sliding window and peak-searching methods, performance measures are calculated for the entire length (typically 0.1 mi) of the segment under this method.
- Nodes (e.g., intersections, ramp terminal intersections, or at-grade rail crossings) are screened by using simple ranking methods.

- Facilities (e.g., a combination of segments and nodes) are screened by using a combination of segment and node screening methods.

Table 6 summarizes the performance measures that are consistent with each screening method. The last column of the table identifies the performance measures that are compatible with *SafetyAnalyst*.

Table 6. Performance Measure Consistency with Screening Methods

Performance Measure	Segments			Nodes	Facilities	In *SafetyAnalyst*?
	Simple Ranking	Sliding Window	Peak Searching			
Average Crash Frequency	Yes	Yes	No	Yes	Yes	Yes
Crash Rate	Yes	Yes	No	Yes	Yes	Yes
EPDO Average Crash Frequency	Yes	Yes	No	Yes	Yes	Yes
Relative Severity Index	Yes	Yes	No	Yes	No	Yes
Critical Crash Rate	Yes	Yes	No	Yes	Yes	No
Excess Predicted Average Crash Frequency Using Method of Moments	Yes	Yes	No	Yes	No	No
Level of Service of Safety	Yes	Yes	No	Yes	No	Yes
Excess Predicted Average Crash Frequency Using SPFs	Yes	Yes	No	Yes	No	Yes
Probability of Specific Crash Types Exceeding Threshold Proportion	Yes	Yes	No	Yes	No	Yes
Excess Proportion of Specific Crash Types	Yes	Yes	No	Yes	No	Yes
Expected Average Crash Frequency with EB Adjustment	Yes	Yes	Yes	Yes	No	Yes
EPDO Average Crash Frequency with EB Adjustment	Yes	Yes	Yes	Yes	No	Yes
Excess Expected Average Crash Frequency with EB Adjustment	Yes	Yes	Yes	Yes	No	Yes

Source: AASHTO 2010. Highway Safety Manual, Volume I. Table 4-3, Performance Measure Consistency with Screening Methods.

Economic Appraisal. Economic appraisals compare the monetary benefits of a potential crash countermeasure (i.e., benefits associated with a change in crash frequency) to the project costs. The data needed to calculate the change in crash frequency and countermeasure implementation costs are summarized in Table 7.

Table 7. Data Needs for Economic Appraisals

Activity	Data Needed to Calculate Project Benefits
Calculate Monetary Benefit	
Estimate change in crashes by severity	Crash history by severity[a] Current and future AADT volumes Implementation year for expected countermeasure SPF for current and future site conditions (if necessary) Crash modification factors (CMFs) for all countermeasures under consideration
Convert change in crash frequency to annual monetary value	Monetary value of crashes by severity Change in crash frequency estimates[b]
Convert annual monetary value to a present value	Service life of the countermeasure Discount rate (minimum rate of return)
Calculate Costs	
Calculate construction and other implementation costs[c]	Subject to standards for the jurisdiction
Convert costs to present value	Service life of the countermeasure(s) Project phasing schedule

Source: AASHTO 2010. Highway Safety Manual, Volume I. Section 7-3, Data Needs.

[a] Systemwide crash history by severity should be stratified according to facility type and area type.

[b] Change in crash frequency estimates is calculated from primary crash data, SPFs, and/or CMFs.

[c] Calculation of construction and implementation costs would require data such as approximate quantities for proposed countermeasure(s), unit costs, and other estimates of miscellaneous items associated with design and construction of the proposed improvement(s).

Part C – Predictive Method

The HSM Part C, Predictive Method, includes predictive models, which consist of SPFs, CMFs, and calibration factors that have been developed for specific roadway segment and intersection types. These predictive models are used to estimate the predicted average crash frequency for a particular site, using a regression model developed from data from a number of similar sites. The SPFs are the basis of the predictive models and were developed in HSM-related research from the most complete and consistent available FHWA Highway Safety Information System (HSIS) crash and roadway characteristics datasets. However, because crash frequencies can vary significantly from one jurisdiction to another, it is important to calibrate SPFs for application in each jurisdiction for reliable results (Srinivasan and Bauer, 2013).

Part C recommends development of calibration factors for all SPFs being used. Alternatively, agency-specific safety performance functions can be developed (Srinivasan et al. 2013). Table 8 summarizes the SPFs available for Part C, Predictive Method, by facility type.

Table 8. Part C, Predictive Method, SPFs Available by Facility Type and Site Types

Facility Type	Undivided Roadway Segments	Divided Roadway Segments	Intersections			
			Stop Control on Minor Leg(s)		Signalized	
			3-Leg	4-Leg	3-Leg	4-Leg
Rural two-lane, two-way roads (Ch. 10)	✓	–	✓	✓	–	✓
Rural multilane highways (Ch. 11)	✓	✓	✓	✓	–	✓
Urban and suburban arterials (Ch. 12)	✓	✓	✓	✓	✓	✓

Source: AASHTO 2010. Highway Safety Manual, Volume II. Table C-1, Safety Performance Functions by Facility Type and Site Types in Part C.

The 2014 supplement to the HSM extended the predictive method to freeways and ramps. The freeway types are:

- Rural freeway segment with four to eight lanes
- Urban freeway segment with four to ten lanes
- Freeway speed-change lanes associated with entrance ramps and exit ramps

The ramps included in the method are:

- Entrance ramp segment with one or two lanes
- Exit ramp segment with one or two lanes
- Collector-distributor (C-D) road segment with one or two lanes
- Crossroad ramp terminal (many different types are included in the HSM)

To calibrate the Part C SPFs, site and crash data must be collected from 30 to 50 sites for each SPF being calibrated. Details of how to estimate calibration factors are provided in Appendix A of Part C of the HSM. Table 9 presents data requirements for the predictive methods outlined in Chapters 10 through 14 of the HSM. The solid circles (●) represent minimum required data elements, while the open circles (○) represent desired data elements. As noted in the table, actual data are needed for the minimum required data elements, while default assumptions can be used for desired data elements.

Table 9. HSM Data Requirements for Predictive Methods[a]

Detailed Data Requirements	Rural Two-Lane Highways (Chapter 10)	Rural Multilane Highways (Chapter 11)	Urban and Suburban Arterials (Chapter 12)	Freeways (HSM Supplement Chapter 18)	Ramps & C-D Road Segments (HSM Supplement Chapter 19)	Notes
Roadway Segments						
Segment length (miles)	●	●	●	●		Need actual data
Ramp or collector-distributor road segment (miles)					●	Need actual data
Lane width (feet)	●	●		●	●	Need actual data
Shoulder type	●					Need actual data
Shoulder width (paved width, left and right shoulders) (feet)	●	●		●	●	Need actual data
Presence of horizontal curve				○	○	Default assumption is not present
Lengths of horizontal curves and tangents (miles)	●			●	●	Need actual data
Length of curve in segment (cannot exceed segment length or curve length)				●	●	Need actual data
Radii of horizontal curves (feet)	●			●	●	Need actual data
Presence of spiral transition for horizontal curves	○				○	Default assumption based on agency design policy
Superelevation variance for horizontal curves	○					Default assumption is no superelevation variance
Grade (percent)	○					Default assumption based on terrain[b]
Presence of lighting	○	○	○			Default assumption is no lighting
Driveway density (driveways per mile)	○					Default assumption is 5 driveways per mile
Presence of passing lanes	○					Default assumption is not present
Presence of short 4-lane section	○					Default assumption is not present

Table 9. HSM Data Requirements for Predictive Methods (Continued)

Detailed Data Requirements	Rural Two-Lane Highways (Chapter 10)	Rural Multilane Highways (Chapter 11)	Urban and Suburban Arterials (Chapter 12)	Freeways (HSM Supplement Chapter 18)	Ramps & C-D Road Segments (HSM Supplement Chapter 19)	Notes
Roadway Segments (Continued)						
Presence of center two-way left-turn lane	●		●			Need actual data
Presence of centerline rumble strips	○					Default assumption based on agency design policy
Presence of shoulder rumble strips				○		Default assumption is not present
Length of rumble strips (inside and outside shoulders)				●		Need actual data
Roadside hazard rating	○					Default assumption is roadside hazard rating = 3
Presence of automated speed enforcement	○	○	○			Default assumption based on current practice
Sideslope (for undivided roadway segments)		●				Need actual data
Median width (feet) (for divided roadway segments)		●		●		Need actual data
Presence of median			●			Need actual data
Number of driveways by land use type (major commercial, minor commercial, major industrial/institutional, major residential, minor residential, other)						
Speed category (low vs. intermediate or high speed) (based on actual traffic speed or posted speed limit)			●			Need actual data
Average traffic speed on freeway during off-peak periods of the typical day					●	Need actual data
Number of through traffic lanes			●	●	●	Need actual data

Table 9. HSM Data Requirements for Predictive Methods (Continued)

Detailed Data Requirements	Rural Two-Lane Highways (Chapter 10)	Rural Multilane Highways (Chapter 11)	Urban and Suburban Arterials (Chapter 12)	Freeways (HSM Supplement Chapter 18)	Ramps & C-D Road Segments (HSM Supplement Chapter 19)	Notes
Roadway Segments (Continued)						
Presence of on-street parking			●			Need actual data
Type of on-street parking (parallel vs. angle; one side vs. both sides of street)			●			Need actual data
Roadside fixed object density (fixed objects/mile, only obstacles 4-in or more in diameter that do not have a breakaway design are counted)			○			Default assumption based on fixed-object offset and density categories[c]
Presence of entrance speed-change lane					●	Need actual data
Presence of exit speed-change lane					●	Need actual data
Length of speed-change lane (from gore to taper point)				●	●	Need actual data
Presence of barriers (barriers in the median and roadside that are offset from the near edge of traveled way by 30 ft or less)				○		Default assumption is not present
Length of barriers (for barriers in the median and roadside that are offset from the near edge of traveled way by 30 ft or less)				●	●	Need actual data
Offset of barriers (for barriers in the median and roadside that are offset from the near edge of traveled way by 30 ft or less)				●	●	Need actual data
Width of continuous offset median barrier				●		Need actual data
Presence of weaving section				○	○	Default assumption is not present
Weaving section length				●	●	Need actual data
Length of weaving section located in the segment (between the segment's begin and end points)					●	Need actual data

Table 9. HSM Data Requirements for Predictive Methods (Continued)

Detailed Data Requirements	Rural Two-Lane Highways (Chapter 10)	Rural Multilane Highways (Chapter 11)	Urban and Suburban Arterials (Chapter 12)	Freeways (HSM Supplement Chapter 18)	Ramps & C-D Road Segments (HSM Supplement Chapter 19)	Notes
Roadway Segments (Continued)						
Distance to nearest upstream entrance ramp in each travel direction				●		Need actual data
Distance to nearest downstream exit ramp in each travel direction				●		Need actual data
Clear zone width (feet)				●		Need actual data
Milepost of beginning of curve in direction of travel (measured along the right edge of the ramp through lane)					●	Need actual data
Presence of lane added to the ramp or C-D road					●	Need actual data
Presence of lane dropped to the ramp or C-D road					●	Need actual data
Length of taper in the segment (if lane added to or dropped from ramp or C-D road)					●	Need actual data
Intersection Data						
Number of intersection legs (3 or 4)	●	●	●			Need actual data
Type of traffic control (minor road stop or signal control)	●	●	●			Need actual data
Type of traffic control used at the crossroad ramp terminal					●	Need actual data
Intersection skew angle (degrees departure from 90 degrees)	○	○				Default assumption is no skew[d]
Number of approaches with left turn lanes	●	●	●			Need actual data
Number of approaches with right turn lanes	●	●	●			Need actual data
Presence of intersection lighting	●	●	●			Need actual data
Presence of left-turn phasing (signalized intersections only)			●			Need actual data

Table 9. HSM Data Requirements for Predictive Methods (Continued)

Detailed Data Requirements	Rural Two-Lane Highways (Chapter 10)	Rural Multilane Highways (Chapter 11)	Urban and Suburban Arterials (Chapter 12)	Freeways (HSM Supplement Chapter 18)	Ramps & C-D Road Segments (HSM Supplement Chapter 19)	Notes
Intersection Data (Continued)						
Type of left-turn phasing (permissive, protected/ permissive, permissive/ protected, or protected) (signalized intersections only)			●			Prefer actual data, but agency practice may be used as a default assumption
Number of approaches on which right-turn-on-red is prohibited (signalized intersections only)			●			Need actual data
Presence of red-light cameras			●			Need actual data
Maximum number of lanes to be crossed by a pedestrian on any approach (for signalized intersections only)			○			Estimate from number of lanes and presence of median on major road
Presence of bus stops within 1,000 ft of the intersection			○			Default assumption is not present
Presence of schools within 1,000 feet of the intersection			○			Default assumption is not present
Number of alcohol sales establishments within 1,000 ft of the intersection			○			Default assumption is not present
AADT for road segments (vehicles per day)	●	●	●		●	Need actual data
AADT for major road at intersections	●	●	●			Need actual data
AADT for minor road at intersections	●	●	●			Need actual data or best estimate
Pedestrian volumes crossing each intersection leg			○			Estimate with Table 12-15 in HSM
Proportion of freeway AADT volume that occurs during hours where the lane volume exceeds 1,000 vehicles per hour per lane				●		Need actual data

Table 9. HSM Data Requirements for Predictive Methods (Continued)

Detailed Data Requirements	Rural Two-Lane Highways (Chapter 10)	Rural Multilane Highways (Chapter 11)	Urban and Suburban Arterials (Chapter 12)	Freeways (HSM Supplement Chapter 18)	Ramps & C-D Road Segments (HSM Supplement Chapter 19)	Notes
Intersection Data (Continued)						
Freeway AADT volume				●		Need actual data
Upstream entrance ramp AADT volume				●		Need actual data
Downstream exit ramp AADT volume				●		Need actual data

Source: AASHTO 2010. Highway Safety Manual, Volume II. Adapted from Table A-2, Data Needs for Calibration of Part C Predictive Models by Facility Type.

[a] Legend: ● Required; ○ Desirable.

[b] Suggested default values for calibration purposes: CMF = 1.00 for level terrain; CMF = 1.06 for rolling terrain; CMF = 1.14 for mountainous terrain.

[c] CMF estimates may be based on two categories of offset to fixed-object (O_{fo})—either 5 or 20 ft—and three categories of fixed-object density (D_{fo}) – 0, 50, or 100 objects per mile.

[d] If measurements of intersection skew angles are not available, the calibration should preferably be performed for intersections with no skew.

The Part C predictive models have default crash distribution percentages for crash type and crash severity that are used to convert total crash data to crash type and severity data. Replacing these default values with locally derived crash type or severity distributions will improve the reliability of the predictive models. Table 10 summarizes the default distributions, including the corresponding HSM table or equation number for rural two-lane highways, rural multilane arterials, and urban and suburban arterials. Table 11 provides similar information for freeways and ramps in the HSM.

Table 10. Predictive Method Default Crash Distributions – Rural Two-Lane Highways, Rural Multilane Highways, and Urban and Suburban Arterials

Chapter	HSM Table or Equation Number	Type of Roadway Element		Data Element or Distribution that May Be Calibrated
		Roadway Segments	Intersections	
Chapter 10 – Rural Two-Lane, Two-Way Roads	Table 10-3	X		Crash severity by facility type for roadway segments
	Table 10-4	X		Collision type by facility type for roadway segments
	Table 10-5		X	Crash severity by facility type for intersections
	Table 10-6		X	Collision type by facility type for intersections
	Equation 10-18	X		Driveway-related crashes as a proportion of total crashes
	Table 10-12	X		Nighttime crashes as a proportion of total crashes by severity level
	Table 10-15		X	Nighttime crashes as a proportion of total crashes by severity level and by intersection type
Chapter 11 – Rural Multilane Highways	Table 11-4	X		Crash severity and collision type for undivided segments
	Table 11-6	X		Crash severity and collision type for divided segments
	Table 11-9		X	Crash severity and collision type by intersection type
	Table 11-15	X		Nighttime crashes as a proportion of total crashes by severity level and by roadway segment type for divided roadway segments
	Table 11-19		X	Nighttime crashes as a proportion of total crashes by severity level and by roadway segment type for divided roadway segments
	Table 11-24		X	Nighttime crashes as a proportion of total crashes by severity level and by intersection type
Chapter 12 – Urban and Suburban Arterials	Table 12-4	X		Crash severity and collision type for multiple-vehicle nondriveway collisions by roadway segment type
	Table 12-6	X		Crash severity and collision type for single-vehicle crashes by roadway segment type
	Table 12-7	X		Crash severity for driveway-related collisions by roadway segment type
	Table 12-8	X		Pedestrian crash adjustment factor by roadway segment type
	Table 12-9	X		Bicycle crash adjustment factor by roadway segment type
	Table 12-11		X	Crash severity and collision type for multiple-vehicle crashes by intersection type
	Table 12-13		X	Crash severity and collision type for single-vehicle crashes by intersection type
	Table 12-16		X	Pedestrian crash adjustment factor by intersection type for stop-controlled intersections
	Table 12-17		X	Bicycle crash adjustment factor by intersection type
	Table 12-23	X		Nighttime crashes as a proportion of total crashes by severity level and by roadway segment type
	Table 12-27		X	Nighttime crashes as a proportion of total crashes by severity level and by intersection type

Source: AASHTO 2010. Highway Safety Manual, Volume II. Adapted from Table A-3, Default Crash Distributions Used in Part C Predictive Models Which May Be Calibrated by Users to Local Conditions.

Table 11. Predictive Method Default Crash Distributions – Freeways and Ramps

HSM Chapter	HSM Table Number	Data Element or Distribution that May Be Calibrated
Chapter 18 – Freeways	Table 18-6	Multiple-vehicle crashes by crash type for freeway segments
	Table 18-8	Single-vehicle crashes by crash type for freeway segments
	Table 18-10	Ramp-entrance-related crashes by crash type
	Table 18-12	Ramp-exit-related crashes by crash type.
Chapter 19 - Ramps	Table 19-6	Multiple-vehicle crashes by crash type and severity for ramp and C-D road segments
	Table 19-9	Single-vehicle crashes by crash type and severity for ramp and C-D road segments
	Table 19-16	Signal-controlled ramp terminal crashes by crash type and severity
	Table 19-21	One-way stop-controlled ramp terminal crashes by crash type and severity
	Table 19-45	All-way stop-controlled ramp terminal crashes by crash type and severity

Relationship of HSM Methods to SafetyAnalyst

Many of the roadway safety management procedures in the HSM can be implemented by using *SafetyAnalyst*. For example, HSM Part B includes both traditional and state-of-the-art safety analysis approaches like those included in *SafetyAnalyst*. The HSM presents a broader range of analytical methods, but the preferred (most unbiased) methods are identical or very similar to those presented in *SafetyAnalyst*. For some methods, the computational approach in the HSM is slightly simpler than the comparable *SafetyAnalyst* approach so that users can more easily perform manual computations. Refer again to Table 6 for a summary of network screening performance measures in the HSM and a list of which performance measures are included in *SafetyAnalyst*.

CHAPTER 3. LESSONS LEARNED FROM STATES: WASHINGTON AND OHIO

This chapter describes the implementation of *SafetyAnalyst* in two other states. The research team conducted on-site interviews with staff from Ohio Department of Transportation (ODOT) and Washington State Department of Transportation (WSDOT). Through these extended interviews, the research team learned details about each state's development, deployment, and application of *SafetyAnalyst*. The agenda for both meetings is included in Appendix A.

ODOT Lessons Learned

The ODOT interview was conducted on February 28 and March 1, 2013. Derek Troyer, transportation engineer, Office of Systems Planning and Program Management, and Lavinia Sugarman, IT systems analyst, were present and participated in all topics of the interview. David Blackstone, manager, Office of Technical Services, was present and participated only for the discussion about data and data management.

ODOT staff provided presentation materials (Appendix B) responding to many of the questions in the meeting agenda. The following topics were discussed:

- The *SafetyAnalyst* Story at ODOT
- How ODOT Is Using *SafetyAnalyst*
- Implementing *SafetyAnalyst* – Data, Schema, Integration, Warehouse
- Implementing *SafetyAnalyst* – IT Needs
- Implementing *SafetyAnalyst* – Staffing and Organizational Requirements
- Lessons Learned

The SafetyAnalyst Story at ODOT

- ODOT began beta testing *SafetyAnalyst* in 2007 and had a fully functional model in 2010. ODOT believes that the development time frame would be much shorter now that many of the software bugs have been fixed.
- ODOT staff strongly encourage other DOTs to implement *SafetyAnalyst* in a phased approach (for example, by starting with two-lane rural highways in a particular district or region).

How ODOT Is Using SafetyAnalyst

- ODOT is currently using only the network screening module; they are in the process of developing and populating the data in the model to apply the evaluation module.
- The diagnosis module is available; they believe it is most useful to younger/less experienced engineers and planners. They believe that staff with more experience are not relying on this module. They also use the diagnosis module to confirm potential countermeasures or to see whether *SafetyAnalyst* identifies different solutions.

- ODOT does not apply the network screening results directly from the software. ODOT postprocesses the rankings provided by *SafetyAnalyst* to address department considerations and priorities.
- *SafetyAnalyst* is developed and deployed at the central office. District offices are provided a version of the model for use in district safety evaluations.
- ODOT has used *SafetyAnalyst* as part of a recent long-range state transportation planning project. Forecast travel demand model volumes were input into the *SafetyAnalyst* model to forecast safety characteristics.
- They have not done a formal validation process; however, their reality checks indicate reasonable results. They are evaluating fewer sites, but they are identifying previously unidentified sites and sites with more severe crashes.
- ODOT plans to use *SafetyAnalyst* in the design exception process. Although this concept was not explored in detail, it is anticipated that the diagnosis and countermeasure selection module will be used.

Implementing SafetyAnalyst – Data, Schema, Integration, Warehouse

- ODOT uses a single-line inventory as the base roadway network with all event data tied to the cardinal direction of the linear referencing system (LRS) feature. They update the *SafetyAnalyst* network annually on or near December 31 to coincide with and take advantage of the Highway Performance Monitoring System (HPMS) submission.
- ODOT previously considered an intersection to be where a state route crossed a state route. Now they consider any crossing an intersection for *SafetyAnalyst*.
- ODOT strongly recommends starting small with regard to data/functionality and then expanding as each element is proofed and as anticipated results are verified. They recommend starting with a small area of geography and minimum events to work out errors, then expanding events, and then expanding geography in a pilot project.
- ODOT maintains a countermeasures list in Excel with an identification (ID) number and From/To measures for loading into *SafetyAnalyst*.
- ODOT learned to assume some data values to enable data processing where values do not exist.

Implementing SafetyAnalyst – IT Needs

- ODOT stated that a *SafetyAnalyst* data administrator should have a functional understanding of the data's meaning and how datasets interact with *SafetyAnalyst*. The data administrator should be a data/systems expert and not an end user. The data administrator is responsible for the initial loading of data into *SafetyAnalyst* and the data preprocessing.
- ODOT uses a blend of the stand-alone and enterprise deployment models. ODOT uses the stand-alone deployment to load, validate, postprocess, and calibrate the data. Then ODOT loads data into the enterprise database and distributes end-user applications for both the stand-alone

model (data and application bundled) and the enterprise model (application pointing to enterprise database).

- ODOT highly recommends using the local (stand-alone) Derby database to work out data issues, as there are “leaks” and bugs in the data preprocessing at the enterprise level (Oracle/SQL Server).
- The output log file is very useful in validating and troubleshooting the data loading, processing, and calibration processes. ODOT recommends distributing the log file to *SafetyAnalyst* experts (data administrator and subject matter experts) to help work through output errors and warnings. The log file can be verbose and hard to decipher, so distribution should be limited to the *SafetyAnalyst* Working Group.
- ODOT recommends the use of a software product called DB Visualizer to examine data. This is a freeware product that can interpret and visualize Derby tables.
- The *SafetyAnalyst* distribution packet for ODOT is approximately 2.35 GB; end users need sufficient hard drive space, as well as the recommended 16 GB Ram on a 64-bit Windows 7 machine.

Implementing SafetyAnalyst – Staffing and Organizational Requirements

- ODOT highly recommends participating in the biweekly webinars sponsored by ITT Expelis and MRIGlobal. Data and applications webinars are available.

Lessons Learned

- The IT person and the planner/engineer working on the project need to have a good relationship and a keen interest in successful implementation of the software.
- ADOT should plan to implement the software in phases to achieve early successes. Consider starting with a subarea of the state and a subcomponent of the transportation system.

WSDOT Lessons Learned

The WSDOT interview was conducted on March 21, 2013. Mark Finch, manager, Geographic Information System (GIS) and Roadway Data Office; Mary Soule, IT; Matt Neely, priority programming engineer, Capital Program Development Management; and John Milton, risk management director, were all present and participated in the interview. The following topics were discussed:

- The SafetyAnalyst Story at WSDOT
- How WSDOT Is Using SafetyAnalyst
- Implementing SafetyAnalyst – Data, Schema, Integration, Warehouse
- Implementing SafetyAnalyst – IT Needs
- Implementing SafetyAnalyst – Staffing and Organizational Requirements
- Lessons Learned

The SafetyAnalyst Story at WSDOT

- WSDOT was a pilot participant with ITT Expelis and MRIGlobal in the testing and "debugging" of *SafetyAnalyst*. They began working with ITT Expelis and MRIGlobal in 2009, and their data were input and running within eight months.
- They had weekly meetings with the IT staff person, the responsible data stewards, and the planners/engineers to work through the variety of implementation questions. WSDOT believes that having the programmer, the data stewards, and the "client" (i.e., the planner/engineer) participating throughout the development of the tool was key to its successful implementation.
- Like ODOT staff, they felt it was imperative that the IT person have an interest in seeing successful implementation of the software.
- They were interested in *SafetyAnalyst* because of the stability of the network screening results from year to year, the diagnosis tools, and the usefulness of the tool in policy and programming decisions.

How WSDOT Is Using SafetyAnalyst

- WSDOT sees *SafetyAnalyst* as a policy tool to support programming decisions. They believe it is important to see the tool in this light to expand its application in safety decision-making.
- WSDOT has other tools available that support additional refined safety analyses. *SafetyAnalyst* is used in the screening and diagnosis stages, which WSDOT considers to be the planning stage of the safety process. As the process moves into scoping and programming, predesign, and design, WSDOT has other tools to support the refined safety analyses. These include visualization tools and the HSM Predictive Method.
- WSDOT "validated" the roadway characteristics and traffic volume data by cross-checking with their data warehouses. The ranking and crash reporting results were verified by experienced WSDOT staff. There was not a quantitative process for verifying the rankings.

Implementing SafetyAnalyst – Data, Schema, Integration, Warehouse

- WSDOT implemented *SafetyAnalyst* using 100^{th}-of-a-mile segments based on their native route segmentation. These "short" segments created statistical variances, so WSDOT is moving towards longer homogenized segments for *SafetyAnalyst*.
- WSDOT is working toward a full *SafetyAnalyst* data schema but is not there yet. The data for ramps and intersections are still in progress, as they are incomplete or not uniform.
- WSDOT identified/assigned three data stewards (Traffic, Roadway, and Crash) to work together to develop and validate data for *SafetyAnalyst*. These three stewards worked well together; without them, the *SafetyAnalyst* implementation might have failed at WSDOT. One of the most critical functions was the identification and documentation of the data crosswalk between WSDOT's native storage and the *SafetyAnalyst* schema.

- WSDOT uses actual linear distance as the linear referencing method (LRM), even though *SafetyAnalyst* asks for mileposts. WSDOT determined that the *SafetyAnalyst* reference to mileposts is actually the software's term for any LRM.
- WSDOT uses an influence area of about 100 feet to tie crashes to an intersection/interchange.
- To validate and obtain traffic control at intersections, WSDOT analyzed crash reports to make assumptions for missing data. WSDOT recommends being creative in developing data that may not exist.
- WSDOT is currently loading more data than the *SafetyAnalyst* schema requires. However, using these data requires using the Agency Override database.
- WSDOT recommends starting small (e.g., one route) and limiting data to prove/test the system.

Implementing SafetyAnalyst – IT Needs

- WSDOT maintains a site license for enterprise distribution; however, they use the stand-alone distribution model. WSDOT could use SQL Server for enterprise distribution but chooses not to.
- The WSDOT distribution packet is 4.5 GB and uses the local Derby database.

Implementing SafetyAnalyst – Staffing and Organizational Requirements

- *SafetyAnalyst* is available to region staff. There is one "power" user in each region and six to 12 people statewide using *SafetyAnalyst* monthly. The central office has provided training.
- As previously described, WSDOT believes the timeline and efficiency of implementing *SafetyAnalyst* can be enhanced if staff is assigned to the deployment. They also believe having the data, IT, and planning/engineering staff working together on development is critical to successful implementation.

Lessons Learned

- WSDOT would have liked to have had one IT person dedicated to the development and implementation of *SafetyAnalyst*. They believe their process would have been quicker and more cost-effective.
- Executive-level buy-in is crucial to the development, ongoing implementation, and licensing of *SafetyAnalyst*. This application is meant to be fully integrated into agency processes over the long term.

Summary

First and foremost, executive-level support for the ongoing development, deployment, and implementation of the tool is necessary. In addition to the staff time, ADOT has already invested in an annual licensing fee of $25,000 (for an enterprise license) . From a development and application perspective, both states emphasized starting with a subset of the state network. This could be a subset of state facilities, or one region within the state, or both; however, the concept is to start small to understand the tool and achieve success on a pilot application. The IT staff and the planner/engineer assigned to the project must be committed to successful implementation and have a positive collaborative relationship. From a time and efficiency perspective, it would be best if this staff could be dedicated 100 percent to the project as the model is being initially deployed.

WSDOT was specifically asked if they would do it again if they had to start all over at a different DOT. Their answer was an absolute yes, with the caveat that the DOT not be data poor. They stated that the time savings using *SafetyAnalyst* versus traditional methods was significant once the data issues had been resolved.

CHAPTER 4. AVAILABLE DATA SOURCES, FORMATS, AND DATA GAPS

To begin the process of identifying ADOT's desires for integration of *SafetyAnalyst* with agency systems and with information resources that satisfy the software's data requirements, the research team conducted on-site interviews with ADOT staff. The research team was specifically interested in understanding ADOT's expectations for the *SafetyAnalyst* implementation and to learn about the availability and possible integration of safety data. The team also included identified and compared existing and desired data conditions.

This chapter is organized into two sections: 1) staff interviews and 2) comparison of existing and desired data conditions.

Staff Interviews

The interviews were conducted in person on April 17, 2013, with staff from ADOT's Multimodal Planning Division (MPD) and the Information Technology Group (ITG). A third interview was conducted by phone with staff from the Traffic Safety Section (TSS) on May 10, 2013. A list of ADOT participants and an interview guide are included in Appendix C.

Multimodal Planning Division (MPD)

Overall, it appears that ADOT maintains most of the necessary data required to support *SafetyAnalyst*. MPD's GIS group maintains these data to support a variety of business uses at the DOT, and they have high confidence in the accuracy of these data on the state route system. MPD GIS maintains an LRS to support the conflation of disparate data sources into unified datasets for analysis and reporting for the HPMS, Certified Public Mileage, State Highway System Log, and others. MPD GIS annually publishes these data reports for the prior calendar year in the summer and publishes LRS updates each quarter. MPD recommends that the *SafetyAnalyst* data refresh cycle coincide with the publication of MPD's data reports for the prior year. This delay (for example, June 2013 is the publish date for calendar year 2012) also is likely to coincide with the publish date of 2012 crash records data to the Safety Data Mart (SDM). Therefore, a data refresh for *SafetyAnalyst* in the summer would enable all data to be assimilated for the prior calendar year.

MPD GIS indicated that while data on the state's highway system are good, data completeness and accuracy drop off as distance from the state routes increases. Urban areas such as Maricopa and LaPaz have fairly good data. Other notes from the conversation include:

- MPD GIS maintains Routes, Intersections, Ramps, and Frontage Roads with unique identifiers in a GIS.
- Features have significant attribution, including roadway characteristics, lanes, tapers/transitions, signalization, ownership, functional class, ramp type, influence areas, traffic volume, etc.
- "Open to traffic" dates before 1992 are estimated.

- Information is limited for intersections/roads that are local and unclassified, but more information is available for intersections/roads that are local and classified.

Information Technology Group (ITG)

ITG would prefer that the *SafetyAnalyst* implementation use an enterprise configuration for the data (i.e., SQL Server) and that as many processes/procedures as possible be automated to reduce or minimize day-to-day staff involvement. ITG will likely lead the final architectural design for the *SafetyAnalyst* implementation. ITG currently has an Exchange Transfer Load (ETL) process established to automatically update the SDM with crash records from ADOT's Accident Location Information Surveillance System (ALISS). A similar ETL should be created to automate the preparation of *SafetyAnalyst* data. ITG suggested starting small with a subarea of the state and a subcomponent of the transportation system to serve as a proof of concept for *SafetyAnalyst*.

ADOT has a standard of using Microsoft SQL Server for enterprise databases, and *SafetyAnalyst* should utilize this RDBMS as its enterprise platform. ITG maintains an enterprise data warehouse, Arizona Information Data Warehouse (AIDW), that normalizes all agency information into a single repository for query and analysis. The AIDW includes both the ALISS crash data from 1992-1993 and MPD GIS information. ITG has also established a computer for the development and deployment of *SafetyAnalyst*. The *SafetyAnalyst* implementation should rely on the new LRS being developed for MPD.

Traffic Safety Section (TSS)

In the long run, the TSS would like to use all modules of *SafetyAnalyst*. The group expects to achieve full implementation of *SafetyAnalyst* through a phased development of the model. TSS expects that network screening will be the most utilized tool after the initial implementation of *SafetyAnalyst*. They expect that central office staff will be the primary, if not only, users of the software. They anticipate that district engineers will ask TSS staff to provide information from *SafetyAnalyst* rather than learn how to use the model themselves. Initially, TSS staff see that *SafetyAnalyst* will be used at a planning/programming level to support the processes of identifying sites with potential for improvement and distributing funds for safety improvements. TSS staff made a few additional notable comments:

- Staff would like easy/direct access to the data from the SDM.
- TSS staff is curious about the amount of data scrubbing necessary before integrating SDM data into *SafetyAnalyst*.
- TSS staff is particularly interested in understanding how terrain type is considered in the *SafetyAnalyst* model.

Comparison of Existing and Desired Data Conditions

Existing Condition

The existing condition of ADOT's *SafetyAnalyst* implementation is highlighted in the diagram in Figure 4. This diagram shows components (people, systems, data) that are integral to a *SafetyAnalyst* implementation and shows how these components are connected and interact with each other at a high level. This Existing Condition diagram will be the basis for the Desired Condition diagram, and the difference between the two ("desired" minus "existing") will provide the baseline for the Gap Analysis in the next chapter.

Desired Condition

The desired condition of ADOT's *SafetyAnalyst* hardware/software/IT implementation is highlighted in Figure 5. This Desired Condition diagram shows components (people, systems, data) that are integral to a *SafetyAnalyst* implementation and shows how these components are connected and interact with each other at a high level. This diagram is based on the Existing Condition diagram, and the difference between the two ("desired" minus "existing") will provide the baseline for the Gap Analysis in subsequent project tasks. Items in red indicate current gaps that are changes from existing conditions. Some components highlighted in red may exist in other formats, but they are shown as gaps that need filling because they require alteration or formatting before they can be used in *SafetyAnalyst*.

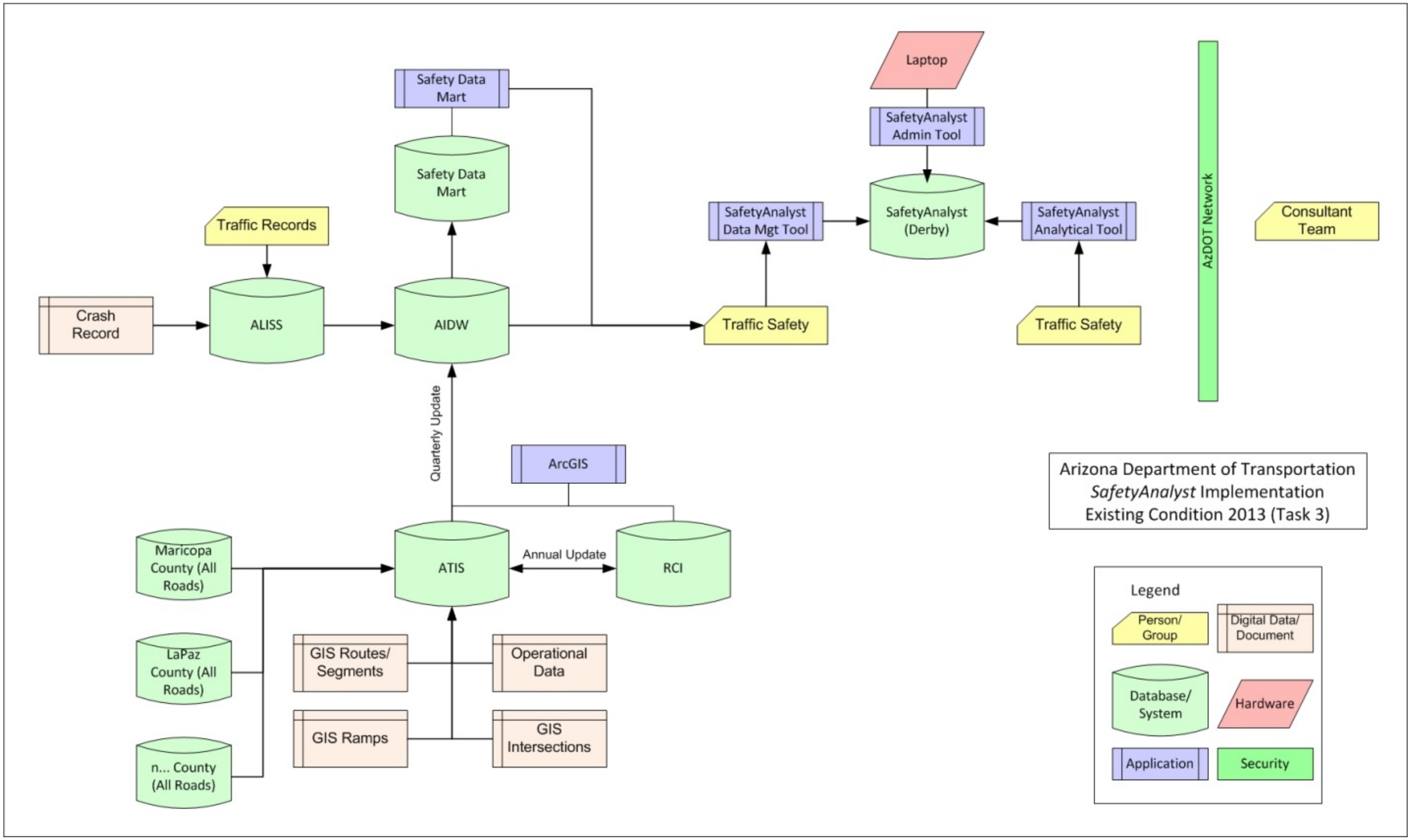


Figure 4. Existing Condition Diagram

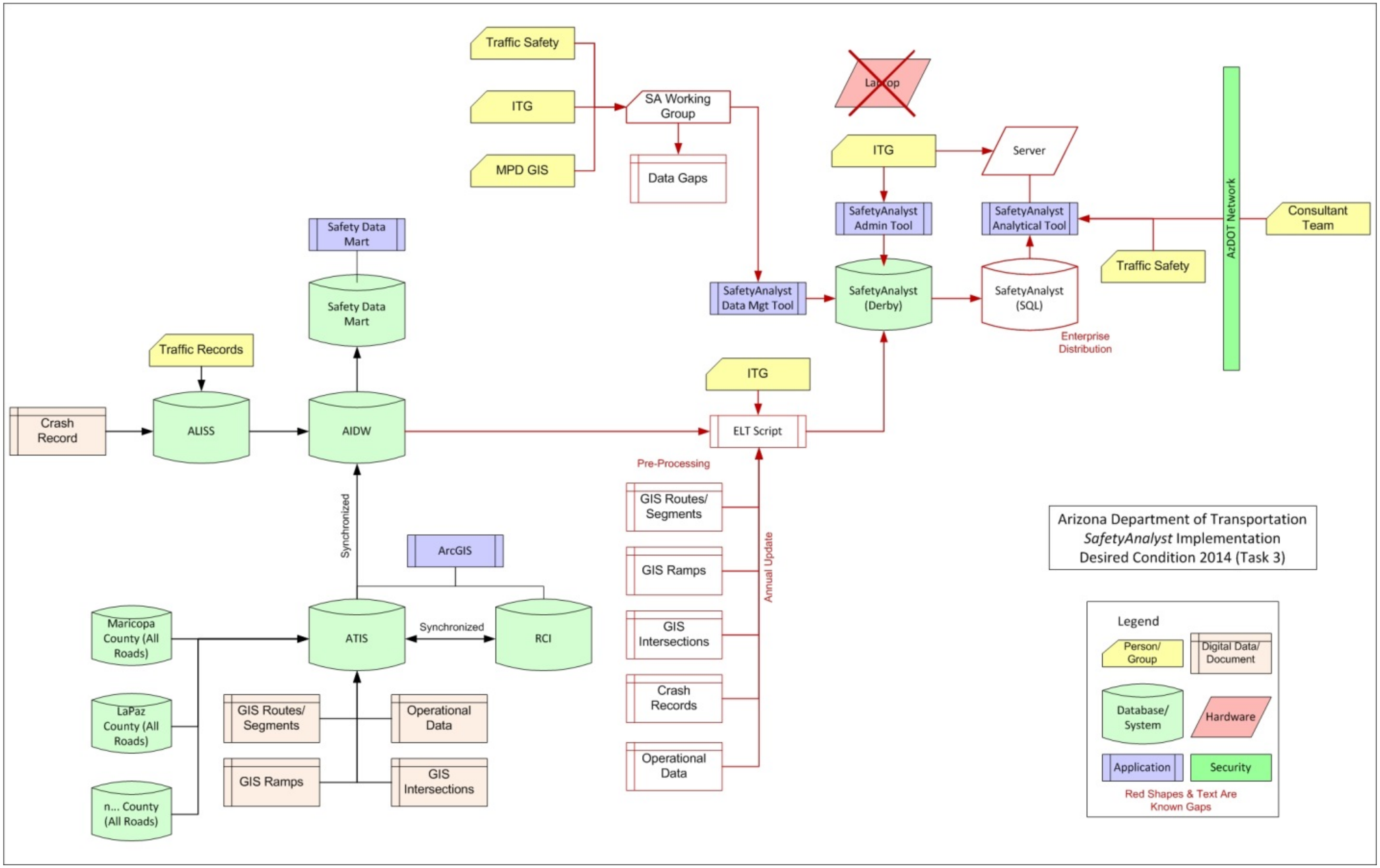


Figure 5. Desired Condition Diagram

Data Sources

The project team was able to identify source locations for all of the data that a successful *SafetyAnalyst* implementation is expected to need. Although there may be specific data gaps in context or coverage, ADOT stores and maintains the necessary data to begin populating the *SafetyAnalyst* schema. The following data sources can be used to support the loading of the *SafetyAnalyst* schema:

- ALISS Database. Crash records, injuries, fatalities, severity, type.
- Arizona Transportation Information System (ATIS). ATIS is an LRS that locates road data to a common spatial reference. This information system includes dual-carriageway routes, ramps, frontage roads, and all local roads functionally classed above “local” and greater than 50 percent of “local roads” depicted statewide.
- Roadway Characteristics Inventory (RCI). The RCI contains all roadway data attribution and is the source of the Certification of Public Road Mileage (CPM)/HPMS and Highway Log data reports and publication.
- SDM. Crash records, injuries, fatalities, severity, type.
- AIDW. Crash records, routes/segments, ramps, intersections, attribution, other business data.

Summary

ADOT is ready to begin implementing *SafetyAnalyst*. ADOT has the data resources and systems necessary to successfully implement the software and analyze the State Highway System using the minimum *SafetyAnalyst* data schema. Eventually, a phased implementation will include all public roads in Arizona.

One item that ADOT should begin to address is an SA Working Group of a few members to review and discuss technical details regarding data conversion, analysis results, processes, and procedures. This committee should be modeled after the best practices of ODOT and WSDOT by comprising data, IT, safety, and traffic engineering subject matter experts. The WSDOT working group had six to eight members. The Ohio DOT had two people responsible for implementation who gathered appropriate input from other experts as needed.

CHAPTER 5. RECOMMENDATIONS ON HOW TO FILL GAPS

This chapter describes the gaps between the existing condition and the desired condition needed for successful implementation of the software. This task included identifying gaps and prioritizing the process of filling these gaps through data variable sensitivity assessment, as well as input from stakeholders, best practices, lessons learned, and other feedback from ADOT on overall system, data, and user needs.

Pilot Deployment

In order to identify the gap between the existing condition and desired condition, the project team conducted a pilot deployment of *SafetyAnalyst* on Interstate 17 from Flagstaff through Phoenix. This study area was selected because it includes both urban and rural areas, a variety of terrain types, and four different system interchanges (at Interstate 40, State Loop 101, Interstate 10 [Papago], and I-10 [Maricopa]). Adjacent roadways included in the pilot network are 30-mile portions of State Loop 303, Forest Road 30 (E. Cornville Road), State Route 169, State Route 179, and Forest Road 213 (Stoneman Lake Road), as well as roadway sections of any other roadways that intersected I-17.

The scope of the pilot effort was limited to crash, roadway, and traffic data for the 544 roadway segments included in the pilot network. Intersections, ramps, and countermeasures (construction projects) were not included in the pilot because of the lack of directly importable data and the level of effort required to process the data into a format suitable for importing. The pilot area was defined as the segments representing the beginning and end of I-17 from Phoenix to Flagstaff. Roadway segments that intersected I-17 or were within a quarter mile of I-17 were included in the pilot. Any roadway segment that crossed I-17 or was within the buffer zone was in the pilot up to the first geographic break point beyond the quarter-mile buffer. Some roadways' first natural break point was several miles from I-17; in these cases, the entire segment was included in the pilot area. In total, the pilot network included 374 miles of roadway, including 148 miles of interstates, 2 miles of U.S. routes, 34 miles of state routes, 123 miles of local routes, and 67 miles of other segments (e.g., ramps and frontage roads). A map of the pilot network is shown in Figure 6. Crash data were obtained for a five-year period from 2008 through 2012. There were 44,345 crashes in/adjacent to the pilot network during this time, consisting of 224 fatality crashes and 1,306 serious injury crashes.

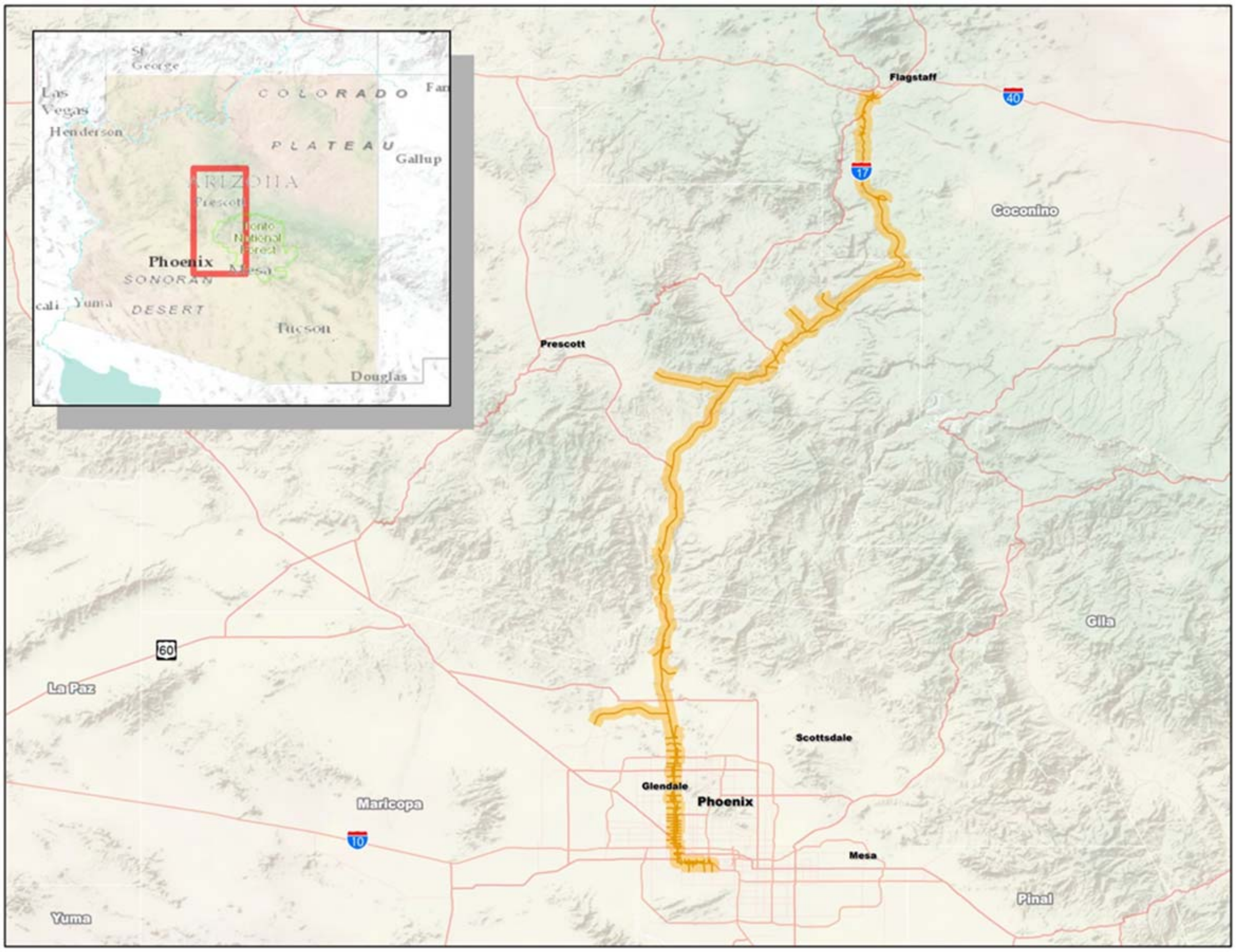


Figure 6. *SafetyAnalyst* Pilot Network

Source: ARCADIS-generated map using ESRI's publicly available ArcGIS Online Basemap Services.

Gap Analysis Between Existing and Desired Condition

Figures 4 and 5 in Chapter 4 depict the existing condition and the desired condition, respectively, for a *SafetyAnalyst* implementation at ADOT. The existing condition represents the current condition of the systems, data, people, and processes and their interaction with *SafetyAnalyst*. The desired condition depicts the ideal systems, data, people, and processes and their interaction with *SafetyAnalyst* as determined by the project team. The differences between the two conditions are gaps that are documented in subsequent sections of this chapter. Each gap between the existing condition and desired condition is categorized by type in Table 12. The pilot included I-17, as well as intersecting routes within a quarter mile of I-17, which include routes that are not part of the state system. For segments on the state system, most of the required data elements exist; however, for segments off the state system, data are scarce and therefore represent a gap. The percentages in Table 12 indicate the percentage of pilot segments missing a data value.

Table 12. Summary of Gaps by Type

Gap Area	Element from Desired Condition	Description
Data Gaps[a]	Routes/Segments	Lane Width – 35% of pilot missing data[b]
		Auxiliary Lane – 10% of pilot missing data
		Median Type – 27% of pilot missing data
		Median Width – 2% of pilot missing data
		Shoulder Type – 24% of pilot missing data
		Shoulder Width – 2% of pilot missing data
		Driveway Density – No data present
		Growth Factor – No data present
		Speed Limit – 38% of pilot missing data
		Bikeway – No data present
		Interchange Influence – No data present
		Open to Traffic – Need specific date (not month and year)
	Ramps	Ramp Type – Can be inferred, but not present
		Ramp Configuration – No data present
		Ramp Freeway Connection – Can be inferred, but not present
		Ramp Crossroad Connection – Can be inferred, but not present
		Ramp Lanes – Can be inferred, but not present
		Open to Traffic (Specific Date) – Can be inferred, but not present
		Ramp Traffic – Some Missing Data
	Intersections	Major Road Direction – Can be inferred, but not present
		Minor Road Name – Can be inferred, but not present
		Intersection Location (Measure on Major Road) – Can be generated
		Minor Road Location (Measure on Minor Road) – Can be generated
		Major Influence Zone Begin – No data present
		Major Influence Zone End – No data present
		Minor Influence Zone Begin – No data present
		Minor Influence Zone End – No data present
		Intersection Type (Configuration) – No data present
		Open to Traffic (Specific Date) – Can be inferred, but not present
		Leg Type – Can be inferred, but not present
		Leg Direction – Can be inferred, but not present
		Leg Through Lanes – Some Missing Data
		Leg Right Turn Lanes – Some Missing Data
		Leg Left Turn Lanes – Some Missing Data
		Leg Median Type – Some Missing Data
		Left Turn Phasing – Some Missing Data
		Leg Speed Limit – Some Missing Data
		Leg Turn Prohibitions – Some Missing Data
		Leg Operational Way – Some Missing Data
		Leg Through Volume – Some Missing Data
		Leg Left Turn Volume – No Data Present
		Leg Right Turn Volume – No Data Present
	Crash Records	Driver Date of Birth (DOB) – No data present
		Driveway Indicator (flag) – No data present
		Direction of Travel vs. Cardinal Direction
	Operational Data	% Heavy Vehicles – 47% of pilot missing data. Data available through a sampling system that did not cover entire pilot network.
		Peak Volume – 47% of pilot missing data. Data available through a sampling system that did not cover entire pilot network.
		AADT – 14% of pilot missing data. *SafetyAnalyst* requires AADT for all analysis years.

Table 12. Summary of Gaps by Type (Continued)

Gap Area	Element from Desired Condition	Description
Data Gaps (Continued)	Construction Project	Project Title
		Start Date
		End Date
		Start Location (Route/Measure)
		End Location (Route/Measure)
		Project Cost
		Project Service Life
	Countermeasure	Site Type
		Construction Start Date
		Construction End Date
		Start Location (Route/Measure)
		End Location (Route/Measure)
		Cost
		Service Life
Application Gaps	ETL Script	The preprocessing of data from native data sources into the required SA formats requires numerous associations, translations, and transformations using GIS and RDBMS operations. If performed manually, the process is very labor intensive, prone to errors, and susceptible to variations in assumptions, processing, and analysis techniques. ADOT should develop an ETL script to automate the preprocessing of data for SA to perform all of the necessary transformations so that this can be performed routinely, with consistent methods and assumptions applied. The ETL will be a grouping of individual GIS and RDBMS operations.
	GIS Data Review Tool	SA does not provide an efficient mechanism for users to review data inputs and analytical outputs for the determination of what is happening at a particular site or location. ADOT should develop a GIS tool to visually display the raw data inputs and analytical tool outputs so that users can visualize these data and their relationships using a GIS. The user also could use the GIS tool to validate raw data inputs or input assumptions and make corrections, if needed. For example, the GIS tool could be used to spot check and validate any assumed data input values based on typical values or ADOT design guidelines.
Database/ System Gaps	*SafetyAnalyst* (SQL)	ADOT needs to create and use a SQL Server database for the distribution of postprocessed SA data. Users will need read-only access and sufficient network connectivity to utilize this resource. The database will require an administrator for performance, connectivity, credentials, and process management.
Hardware Gaps	Database Server	ADOT needs to identify an existing enterprise SQL Server database server for the storage and distribution of postprocessed SA data. This will serve as the distribution point for SA information and will prevent SA data packages from being distributed across the agency as individual Derby databases. If preferred, ADOT can use a new SQL database server; however, the load SA will require does not justify this expense. Any existing SQL implementation with appropriate connectivity and available load will suffice.
	File Distribution Location	ADOT needs to identify an existing location for the distribution of the SA install package (without data) that points to the SQL database server. This file is produced by SA after postprocessing and will be downloaded by SA users for local user install and use of SA postprocessed information (Analytical Tool).
Workflow/ Process Gaps	Preprocessing	The preprocessing of data prior to loading into SA is a highly technical process that uses a variety of analytical techniques. This process should be automated as much as possible to ensure consistent assumptions and analytical results.
	Annual update	ADOT should preprocess, postprocess, and distribute data through an annual update process.

Table 12. Summary of Gaps by Type (Continued)

Gap Area	Element from Desired Condition	Description
Workflow/ Process Gaps (continued)	Enterprise distribution	ADOT should use SQL Server as the data storage and distribution mechanism over individual Derby databases to eliminate data publication and version issues and discrepancies.
	Data/System Changes	ADOT needs a process to implement changes to the data/systems and review the consequences that these changes have on users and the analytics of SA outputs. ADOT should formalize this process and utilize the SA Working Group to make decisions and to test impacts prior to full implementation of changes.
People/ Organization Gaps	*SafetyAnalyst* Working Group	ADOT needs to form a *SafetyAnalyst* Working Group to make critical decisions regarding *SafetyAnalyst* data inputs, assumptions, transformations, and quality control as the data and systems evolve over time. This group should be small and should represent the interested parties within the agency. The group will be responsible for discussing and testing the ramifications of changes to tool operation, data input sources, changes to assumptions, and any other potential change to the overall system. The *SafetyAnalyst* Data Administrator and the SA Application Administrator should participate in this group. This group also should have representation by the end-user community. Members should have data, IT, safety, and traffic engineering expertise.
	SafetyAnalyst Data Administrator (Data Management Tool)	ADOT needs to identify and assign an administrator to be the responsible party for the Data Management Tool. This individual should be an IT/database resource familiar with the data and data requirements for SA. This individual will be responsible for all data preprocessing activities (including future ETLs), loading data into SA, and postprocessing the SA database. This individual also should be responsible for the implementation of any changes in data sources, assumptions, or analytical techniques. This individual should participate in the SA Working Group.
	SafetyAnalyst Application Administrator (Administrator Tool)	ADOT needs to identify and assign an administrator to be the responsible party for the Administrator Tool. This individual should be an IT resource familiar with the workflow and distribution requirements for SA. This individual will be responsible for the licensing of the product, the overall systems involved (SQL Server, file distribution, ETL management, user management, and publication management), and the overall upkeep of the system. This individual should participate in the SA Working Group.

[a] Regarding data gaps, it should be noted that the pilot included I-17, as well as intersecting routes within a quarter mile of I-17; this includes routes that are not part of the state system. For segments on the state system, a majority of the required data elements exists; however, for segments off the state system, data are scarce and therefore constitute a gap.

[b] The percentage indicates the percentage of pilot segments missing a data value.

Prioritization of Gap Components

Tables 13 to 19 describe the overall priority for filling each gap identified in the gap analysis. Each gap is rated on a scale of low/medium/high for investment required, return on investment value, and the ultimate recommended priority for filling each gap. These ratings are defined below.

Explanation of Rating Scale in Tables 13-19

- **Investment Required Value:** Considers the volume of information or cost required to fill the gap, the procedure for how the gap could be filled, and the availability of resources that would be required.
    - **Low –** Little or minimal time, effort, or external cost would be required to fill this gap. Support (data, technology, or information) likely already exists to fill this gap.
    - **Medium –** Some effort or cost will be required to fill the gap. Gap may require a project to fill the gap.

  - **High –** Major effort or cost will be required. Gap may require advanced analysis, field data collection, or significant expense to fill the gap.
- **Return on Investment Value:** Considers the requirements of *SafetyAnalyst* or the user and the additional capability and accuracy that filling the gap may serve.
  - **Low –** Cost in labor, hardware/software, or project fees will likely not be recuperated.
  - **Medium –** Cost in labor, hardware/software, or project fees will provide value to *SafetyAnalyst* or the agency at large, but the return may not equal the investment.
  - **High –** Cost in labor, hardware/software, or project fees will be overshadowed by the value provided by filling the gap.
- **Priority Value:** Considers the investment required, the return on investment, and the overall value to ADOT.
  - **Low –** The investment required and the benefit provided to do not add much value to *SafetyAnalyst* and the agency at large.
  - **Medium –** As time and investments permit, this gap should be filled; however, *SafetyAnalyst* can be implemented without filling this gap.
  - **High –** This gap should be filled as soon as possible as it provides extreme value to *SafetyAnalyst*, or filling this gap is a requirement for a successful and accurate implementation.

Additionally, the overall priority has been influenced by the ability to assume a value when necessary without significantly impacting the end use of *SafetyAnalyst*. For example, if no lane width data are available, lane width can be an assumed value; therefore, resources expended to generate accurate lane width data do not generate a high return on investment and are therefore a low priority.

Table 13. Priorities for Filling Gaps – Routes/Segments

Subtype	Investment Required	Return on Investment	ROI Comments	Priority
Lane Width	Medium	Low	Gap can be populated with assumed data achieving desired result. Accuracy will be diminished.	Low
Auxiliary Lane	Medium	Low	Gap can be populated with assumed data achieving desired result. Accuracy will be diminished.	Low
Median Type	Medium	Medium	Value is important to SA operation	High
Median Width	Medium	Low	Gap can be populated with assumed data achieving desired result. Accuracy will be diminished.	Low
Shoulder Type	Medium	Medium	Value is important to SA operation.	High
Shoulder Width	Medium	Low	Gap can be populated with assumed data achieving desired result. Accuracy will be diminished.	Low
Driveway Density	High	Low	Low value.	Low
Growth Factor	Low	High	Helps with missing volume information.	High
Speed Limit	Medium	Medium	Value is important to SA operation.	High
Bikeway	Medium	Low		Low
Interchange Influence	High	High	Establishes intersection boundaries.	High
Open to Traffic	High	Low	Enables ability to specify temporal analysis.	Low

ROI: Return on Investment

Table 14. Priorities for Filling Gaps – Ramps

Subtype	Investment Required	Return on Investment	ROI Comments	Priority
Ramp Type	Low	Medium	Enables the use of ramps. Ramps currently can be used if they are used as mainlines and not ramps, but specific ramp-based analysis is lost.	Low
Ramp Configuration	Medium	Medium	Enables the use of ramps. Ramps currently can be used if they are used as mainlines and not ramps, but specific ramp-based analysis is lost.	Low
Ramp Freeway Connection	Medium	Medium	Enables the use of ramps. Ramps currently can be used if they are used as mainlines and not ramps, but lose specific ramp-based analysis is lost.	Low
Ramp Crossroad Connection	Medium	Medium	Enables the use of ramps. Ramps currently can be used if they are used as mainlines and not ramps, but specific ramp-based analysis is lost.	Low
Ramp Lanes	Medium	Medium	Enables the use of ramps. Ramps currently can be used if they are used as mainlines and not ramps, but specific ramp-based analysis is lost.	Low
Open to Traffic	High	Low	Enables the use of ramps. Ramps currently can be used if they are used as mainlines and not ramps, but specific ramp-based analysis is lost.	Low
Ramp Traffic	High	Medium	Enables the use of ramps. Ramps currently can be used if they are used as mainlines and not ramps, but specific ramp-based analysis is lost.	Low

Table 15. Priorities for Filling Gaps – Intersections

Subtype	Investment Required	Return on Investment	ROI Comments	Priority
Major Road Direction	Low	High	Enables the use of intersections	Medium
Minor Road Name	Low	High	Enables the use of intersections	Medium
Intersection Location	Low	High	Enables the use of intersections	Medium
Minor Road Location	Low	High	Enables the use of intersections	Medium
Major Influence Zone Begin	High	High	Enables the use of intersections	Medium
Major Influence Zone End	High	High	Enables the use of intersections	Medium
Minor Influence Zone Begin	High	High	Enables the use of intersections	Medium
Minor Influence Zone End	High	High	Enables the use of intersections	Medium
Intersection Type (Configuration)	High	High	Enables the use of intersections	Medium
Open to Traffic	High	Low	Enables the use of intersections	Low
Leg Type	Medium	High	Enables the use of intersections	Medium
Leg Direction	Medium	High	Enables the use of intersections	Medium
Leg Through Lanes	Medium	High	Enables the use of intersections	Medium
Leg Right-Turn Lanes	Medium	High	Enables the use of intersections	Medium
Leg Left-Turn Lanes	Medium	High	Enables the use of intersections	Medium
Leg Median Type	Medium	High	Enables the use of intersections	Medium
Left-Turn Phasing	Medium	High	Enables the use of intersections	Medium
Leg Speed Limit	Medium	High	Enables the use of intersections	Medium
Leg Turn Prohibitions	High	High	Enables the use of intersections	Medium
Leg Operational Way	High	High	Enables the use of intersections	Medium
Leg Through Volume	High	High	Enables the use of intersections	Medium
Leg Left-Turn Volume	High	High	Enables the use of intersections	Medium
Leg Right-Turn Volume	High	High	Enables the use of intersections	Medium

Table 16. Priorities for Filling Gaps – Crash Records and Operational Data

Subtype	Investment Required	Return on Investment	ROI Comments	Priority
Driver Date of Birth	Low	Low	Extra Summary Element	Low
Driveway Indicator	High	Low	Extra Summary Element	Low
Direction of Travel vs. Cardinal Direction	High	High	Validation that crashes are correctly coded to route and establishes proper travel direction of vehicle not route direction	High
% Heavy Vehicles	High	High	Critical Analysis Input	High
Peak Volume	High	High	Critical Analysis Input	High
AADT	High	High	Critical Analysis Input	High

Table 17. Priorities for Filling Gaps – Construction Projects

Subtype	Investment Required	Return on Investment	ROI Comments	Priority
Project Title	Medium	Low	Enables the use of construction and countermeasures	Low
Start Date	Medium	Low	Enables the use of construction and countermeasures	Low
End Date	Medium	Low	Enables the use of construction and countermeasures	Low
Start Location	Medium	Low	Enables the use of construction and countermeasures	Low
End Location	Medium	Low	Enables the use of construction and countermeasures	Low
Project Cost	High	Low	Enables the use of construction and countermeasures	Low
Project Service Life	High	Low	Enables the use of construction and countermeasures	Low

Table 18. Priorities for Filling Gaps – Countermeasures

Subtype	Investment Required	Return on Investment	ROI Comments	Priority
Site Type	Medium	Low	Enables the use of construction and countermeasures	Low
Construction Start Date	Medium	Low	Enables the use of construction and countermeasures	Low
Construction End Date	Medium	Low	Enables the use of construction and countermeasures	Low
Start Location	Medium	Low	Enables the use of construction and countermeasures	Low
End Location	Medium	Low	Enables the use of construction and countermeasures	Low
Cost	High	Low	Enables the use of construction and countermeasures	Low
Service Life	High	Low	Enables the use of construction and countermeasures	Low

Table 19. Priorities for Filling Gaps – Additional Gaps

Gap Area	Element	Investment Required	Return on Investment	ROI Comments	Priority
Application Gap	ETL Script	High	High	Data, analysis, and procedures standardization	High
	GIS Data Review Tool	Medium	High	Increased understanding of analysis inputs and results	High
Database System Gap	*SafetyAnalyst* SQL	Low	High	Centralized data distribution	High
Hardware Gap	Database Server	Low	High	Centralized data distribution	High
	File Distribution Location	Low	High	Centralized data distribution	High
Workflow Process Gap	Preprocessing	High	High	Data, analysis, and procedures standardization	High
	Annual update	Medium	Medium	Updated data	Medium
	Enterprise distribution	Low	High	Data, analysis, and procedures standardization	High
	Data/System Changes	Medium	High	Refinement of analytical outputs and testing of changes to continuously improve the system	High
Staffing and Organization Gap	*SafetyAnalyst* Working Group	Low	High	Refinement of analytical outputs and testing of changes to continuously improve the system	High
	SafetyAnalyst Data Administrator (Data Management Tool)	Low	Medium	Administration of system	High
	SafetyAnalyst Application Administrator (Administrator Tool)	Low	Medium	Administration of system	High

Recommendations for Filling Gaps

After numerous data loading trials to populate the pilot database, the project team determined that it is in ADOT's best interest to always provide a data value for each data element. A null or blank value always resulted in *SafetyAnalyst's* rejecting the data record. In addition, *SafetyAnalyst* rejected records where critical data elements were marked as "unknown" or "other." Therefore, it is critical that all values in the database be populated with a value. Given this information, the project team recommends providing an assumed value for each data element if data are not available. These data assumptions should be carefully recorded and updated as data replacing the assumptions are collected, and sensitivity analyses should be conducted to evaluate assumptions.

A validation should be conducted to ensure that the input data records are being processed correctly by *SafetyAnalyst*. This can be done by comparing the preprocessed and postprocessed data for various network descriptive elements, such as number of roadway segments, number of intersections, number of ramps, and number of crashes by segment. Ensuring that all values in the database are populated with a value will minimize the number of data records rejected by *SafetyAnalyst*.

Tables 20 to 25 show recommendations for how ADOT can fill data gaps with actual or assumed data values that will allow the analytical tool to process data with these gaps.

Table 20. Recommendations for Filling Gaps – Routes/Segments

Subtype	Filling Recommendations
Lane Width	Collect data or use Roadway Design Guidelines, pg. 300-2 (12 ft)
Auxiliary Lane	Collect data or assign None (0)
Median Type	Collect data or assign an average value based upon roadway type and area
Median Width	Collect data or assign an average value based upon roadway type and area
Shoulder Type	Collect data or assign an average value based upon roadway type and area
Shoulder Width	Collect data or assign an average value based upon roadway type and area
Driveway Density	Collect data or assign an average value based upon roadway type and area
Growth Factor	Collect data or apply general assumption value
Speed Limit	Collect data or assign an average value based upon roadway type and area
Bikeway	Collect data from aerial photo or photo log
Interchange Influence	Collect or assign values or apply assumed value by roadway type, area, and intersection type
Open to Traffic	Collect data or apply a general rule to value. If year known, make January 1; if month and year known, make first of month.

Table 21. Recommendations for Filling Gaps – Ramps

Subtype	Filling Recommendations
Ramp Type	Collect data or infer from ramp number
Ramp Configuration	Collect data from aerial photo or photo log
Ramp Freeway Connection	Collect data from aerial photo or photo log
Ramp Crossroad Connection	Collect data or infer from ATIS Code on cross road
Ramp Lanes	Collect data from aerial photo or photo log
Open to Traffic	Collect data or apply a general rule to value. If year known, make January 1; if month and year known, make first of month.
Ramp Traffic	Collect data or assign a value based upon area type

Table 22. Recommendations for Filling Gaps – Intersections

Subtype	Filling Recommendations
Major Road Direction	Determine from ATIS Code and Road Type
Minor Road Name	Assign ATIS Code from intersecting feature
Intersection Location	Overlay with LRS for measure
Minor Road Location	Overlay with LRS for measure
Major Influence Zone Begin	Collect data or apply general assumption value based upon roadway type and area type
Major Influence Zone End	Collect data or apply general assumption value based upon roadway type and area type
Minor Influence Zone Begin	Collect data or apply general assumption value based upon roadway type and area type
Minor Influence Zone End	Collect data or apply general assumption value based upon roadway type and area type
Intersection Type (Configuration)	Collect data from aerial photo or photo log
Open to Traffic	Collect data or apply a general rule to value. If year known, make January 1; if month and year known, make first of month
Leg Type	GIS Relationship Analysis using ATIS Code and Intersection Location
Leg Direction	GIS Relationship Analysis using ATIS Code and Intersection Location
Leg Through Lanes	GIS Relationship Analysis using ATIS Code and Intersection Location
Leg Right-Turn Lanes	GIS Relationship Analysis using ATIS Code and Intersection Location
Leg Left-Turn Lanes	GIS Relationship Analysis using ATIS Code and Intersection Location
Leg Median Type	Collect data or assign an average value based upon roadway type and area
Left-Turn Phasing	Collect data
Leg Speed Limit	Collect data or assign an average value based upon roadway type and area
Leg Turn Prohibitions	Collect data
Leg Operational Way	Collect data
Leg Through Volume	Collect data or investigate traffic models at ADOT, regional, and local levels
Leg Left-Turn Volume	Collect data or investigate traffic models at ADOT, regional, and local levels
Leg Right-Turn Volume	Collect data or investigate traffic models at ADOT, regional, and local levels

Table 23. Recommendations for Filling Gaps – Crash Records and Operational Data

Subtype	Filling Recommendations
Driver Date of Birth	Calculate from Driver’s Age on the date of the crash. Use first day of the crash month as the birth date/month.
Driveway Indicator	Change Crash Report Form to collect data
Direction of Travel vs. Cardinal Direction	Analyze existing data and determine path forward
% Heavy Vehicles	Collect data or assignment by roadway type using average T factor (Interstates 13%, SR 9%, US 9%, Local 5%)
Peak Volume	Collect data or assignment by roadway type using average K factor (Interstates 9%, SR 9%, US 10%, Local 20%)
AADT	Average similar site subtypes values. Ensure values are provided for each analysis year, and apply growth factor to adjacent year AADT if data not available for a specific year.

Table 24. Recommendations for Filling Gaps – Construction Projects and Countermeasures

Subtype	Filling Recommendations
Project Title	Derive from GIS Project Segments
Start Date	Derive from GIS Project Segments
End Date	Derive from GIS Project Segments
Start Location	Derive from GIS Project Segments
End Location	Derive from GIS Project Segments
Project Cost	Collect data
Project Service Life	Collect data
Site Type	Collect data
Construction Start Date	Collect data
Construction End Date	Collect data
Start Location	Collect data
End Location	Collect data
Cost	Collect data
Service Life	Collect data

Table 25. Recommendations for Filling Additional Gaps

<table>
<tr><th>Gap Area</th><th>Element</th><th>Filling Recommendations</th></tr>
<tr><td rowspan="2">Application Gap</td><td>ETL Script1</td><td>Create a script to pull data from the source location and analyze, translate, and transform into the SA loading template</td></tr>
<tr><td>GIS Data Review Tool</td><td>Create an ArcGIS Server site with the source data, the SA loading data, and the analytical tool output for investigation and exploration by the end user</td></tr>
<tr><td>Database/ System Gap</td><td>SafetyAnalyst SQL</td><td>Create a SQL Server database within an existing SQL Instance</td></tr>
<tr><td rowspan="2">Hardware Gap</td><td>Database Server</td><td>Create a SQL Server database within an existing SQL Instance</td></tr>
<tr><td>File Distribution Location</td><td>Create an ftp site location or a file server location accessible to all SA users</td></tr>
<tr><td rowspan="4">Workflow/ Process Gap</td><td>Preprocessing</td><td>Create automated ETL scripts to enable routing populate of SA loading data</td></tr>
<tr><td>Annual update</td><td>Create automated ETL scripts to enable routing populate of SA loading data</td></tr>
<tr><td>Enterprise distribution</td><td>Create a SQL Server database within an existing SQL Instance</td></tr>
<tr><td>Data/System Changes</td><td>Create SA Working Group to review data and processes</td></tr>
<tr><td rowspan="3">People/ Organization Gap</td><td>SafetyAnalyst Working Group</td><td>Create group of SA Application Administrator, Data Administrator, and one or two SA end users</td></tr>
<tr><td>SafetyAnalyst Data Administrator (Data Management Tool)</td><td>Nominate a database expert from ITG</td></tr>
<tr><td>SafetyAnalyst Application Administrator (Administrator Tool)</td><td>Nominate a systems expert from ITG</td></tr>
</table>

CHAPTER 6. RECOMMENDED *SAFETYANALYST* IMPLEMENTATION

This chapter provides recommendations for integrating *SafetyAnalyst* into standard business practices at ADOT. The research team identified preliminary options for *SafetyAnalyst* integration; assessed the strengths/weaknesses of each option based on an assessment of data availability, data collection priorities, user needs, and system requirements; and developed a recommended *SafetyAnalyst* implementation.

Potential Use of SafetyAnalyst

SafetyAnalyst has four modules:

- **Module 1 – Network Screening**. This module allows users to review the entire roadway network and identify sites with potential for safety improvements.
- **Module 2 – Diagnosis and Countermeasure Selection.** This module helps users diagnose safety problems at a specific site and select appropriate countermeasures.
- **Module 3 – Economic Appraisal and Priority Ranking.** This module allows users to conduct an economic analysis of a specific countermeasure or several alternative countermeasures for a specific site. The priority ranking functionality ranks countermeasures by the benefit and cost estimates determined by the economic appraisal.
- **Module 4 – Countermeasure Evaluation.** This module is used to estimate the safety effect of countermeasures implemented at specific site.

This section describes how each module could be applied within the functions of ADOT's Traffic Safety Section and ADOT's project development process.

Potential Use of SafetyAnalyst to Support the HSIP

ADOT administers HSIP funding for the state highway system and local roadways through the ADOT TSS. ADOT districts submit requests for safety improvement funding for locations within their jurisdiction. At the local level, HSIP funding is distributed through local metropolitan planning organizations (MPO) or councils of governments (COG); these local agencies are responsible for identifying high-crash locations using any acceptable screening method and identifying high-priority safety improvement projects based on local need. ADOT assists local agencies with the process of identifying and developing projects, and formal evaluations are conducted through the Road Safety Assessment program to support local, Tribal, state, and federal agencies. ADOT reviews all projects statewide and prioritizes them for funding eligibility. ADOT also encourages MPOs and COGs to apply for state funds for projects. (*Associated ADOT business units: Roadway Engineering – Traffic Safety Section, Local Public Agency Section*) (Source: http://safety.fhwa.dot.gov/p2p/region9/)

Relevant *SafetyAnalyst* modules for these activities include the following:

- **Module 1: Network Screening Tool.** The Network Screening tool could be used by TSS or MPO/COG staff to identify sites with higher-than-expected crash frequencies or high proportions of specific crash types. If *SafetyAnalyst* implementation is limited to TSS, a list of top-ranked crash locations by area/facility type could be generated and distributed to MPOs/COGs to support the identification of high-crash locations at the local level.
- **Module 2: Diagnosis and Countermeasure Selection Tools.** The Diagnosis and Countermeasure Selection tools could be used by TSS or MPO/COG staff to diagnose crash patterns within the list of top-ranked crash locations and identify appropriate countermeasures to reduce traffic fatalities and serious injuries at these locations. Both spot treatments and systemic safety improvements could be identified. The tools could also support field condition reviews conducted as part of engineering studies and road safety assessments by generating a list of site-specific questions regarding site characteristics, crash experience, geometric design, and traffic control characteristics at the site.
- **Module 3: Economic Appraisal and Priority Ranking Tools.** The Economic Appraisal and Priority Ranking tools could be used by MPO/COG staff to conduct economic appraisals of the costs and safety benefits among various projects that could be included in HSIP applications. ADOT staff could use the tools to identify the mix of projects, countermeasures, deployment levels, and funding needed to achieve its targeted goals for reducing fatalities and serious injury crashes on Arizona roadways. Ranking of priority for inclusion in the HSIP is based on benefit-cost ratio and available funding.
- **Module 4: Countermeasure Evaluation Tool.** The Countermeasure Evaluation tool could be used by ADOT staff to demonstrate the effectiveness of HSIP improvements by evaluating the change in crash frequency or severity (i.e., safety effectiveness) associated with projects once they have been in operation long enough to yield three to five years of crash data. The tool is capable of performing benefit-cost analyses for implemented countermeasures, which are needed for evaluations of federally funded HSIP projects.

Potential Use of SafetyAnalyst Within ADOT's Project Development Process

This section describes the potential use of *SafetyAnalyst* within the individual stages of ADOT's overall project development process and the ADOT business units that are associated with each stage.

Stage 1: Long-Range Planning. Identify priorities, projects, programs, and/or policies to address long-term system needs for roadways and multimodal forms of transportation, such as public transit, pedestrian, bicycling, and aviation. ADOT's planning program begins with a long-range visioning process, moves into a 20-year Long-Range Transportation Plan, and finally yields a Five-Year Transportation Facilities Construction Program. The Long-Range Transportation Plan sets priorities, while the actual projects are selected in the Five-Year Program (*Associated ADOT Business Unit: Multimodal Planning Division, Transportation Planning*).

Relevant *SafetyAnalyst* modules for these activities include the following:

- **Module 1: Network Screening.** Sites identified with potential for safety improvement could be considered or integrated into the five-year planning and programming activities.
- **Module 2: Diagnosis and Countermeasure Selection Tools.** *SafetyAnalyst* could be used to identify crash contributing factors, crash types, and possible countermeasures for sites (intersections or segments) being considered as part of the five-year planning and programming process. Site safety improvements could be integrated with other project considerations (e.g., traffic operations improvements) or could be used as the primary driver for improvements.

Stage 2: Project Scoping. Identify the preferred alignment for a project, including a clear description of the project scope, budget, and major design features/requirements. Project scoping is initiated five to seven years prior to construction, and the results are documented in a project scoping letter, project assessment (PA), or location/design concept report (L/DCR). TSS assists with project scoping activities by conducting safety evaluations, which consist of a review of crash history to identify potential safety issues within the project limits, review of field conditions to assess potential safety improvements, and consideration of available funds; on a few projects, TSS applies the Interactive Highway Safety Design Model (IHSDM) to evaluate changes in crash frequency or severity associated with alternative cross sections. The results of the safety evaluation are used to assess the benefit of various design alternatives in addressing safety issues (*Associated ADOT Business Units: Roadway Engineering – Roadway Predesign and Review Section, Traffic Safety Section*).

Relevant *SafetyAnalyst* modules for these activities include the following:

- **Module 1: Network Screening.** The *SafetyAnalyst* Network Screening results could indicate whether a site under investigation has the potential for safety improvement and, thus, whether additional safety-specific treatments should be considered.
- **Module 2: Diagnosis and Countermeasure Selection Tools.** The *SafetyAnalyst* Diagnosis tool could be used to diagnose crash patterns within the project limits to determine whether there are particular safety concerns that should be included in the project's purpose and need statement. To support a safety evaluation, users could generate crash summary statistics, collision diagrams, and statistical tests for the site to determine whether certain crash types are overrepresented. *SafetyAnalyst* could support the field condition review by generating a list of site-specific questions regarding site characteristics, crash experience, geometric design, and traffic control at the site. The results of the field investigation could be entered into *SafetyAnalyst* to generate a list of suggested countermeasures to improve safety for roadway segments and intersections. Users could select one or more of the suggested countermeasures for consideration in the safety evaluation and add other countermeasures they consider appropriate.
- **Module 3: Economic Appraisal and Priority Ranking Tools.** The Economic Appraisal tool could be used to conduct economic appraisals of the costs and safety benefits of alternative countermeasures for a particular site and narrow down design alternatives for recommendation

and advancement into the design stage. The Priority Ranking tool could be used to rank the priority of proposed improvement projects for the site based on the benefit-cost analysis results. The results could be used to select countermeasures for incorporation into the project scope.

Stage 3: Programming. Prioritize and program a project that has completed all of the planning and environmental requirements to proceed into the final design stage. Information from the scoping phase is used in the priority programming process. The resulting projects are included in the Five-Year Transportation Construction Program (*Associated ADOT Business Unit: Multimodal Planning Division – Transportation Programming*).

Relevant *SafetyAnalyst* modules for these activities include the following:

- **Module 3: Economic Appraisal and Priority Ranking Tools.** The Economic Appraisal tool could be used to conduct a benefit-cost analysis to compare safety benefits among various projects and assist ADOT in setting priorities for safety countermeasures across a network. The Priority Ranking tool could be used to compare the benefits and costs of projects across sites and prioritize projects by cost effectiveness, benefit-cost ratio, or net present value. The safety benefits of projects could be compared alongside capacity, operational, or connectivity needs, and the results could be incorporated into programming decisions to select projects for the Five-Year Program. Performance measures, such as changes in crash frequency or severity, could be a consideration in the decision-making process for certain types of improvements. Potential traffic operations and/or economic impacts could also be considered. As the model expands to include more roads in the state, ADOT could consider integrating the model with the Planning to Programming (P2P) process that is currently under development at ADOT.

Stage 4: Project Development/Design. Develop detailed design submittals (30 percent, 60 percent, 95 percent, 100 percent complete) in accordance with ADOT design-related policies, guidelines, and standard plans. At the conclusion of project development, ADOT advertises the project, accepts bids from qualified contractors, and awards the project to the selected contractor (*Associated ADOT Business Unit: Roadway Engineering – Roadway Design*).

Relevant *SafetyAnalyst* modules for these activities include the following:

- **Module 2: Diagnosis and Countermeasure Selection Tools.** The Diagnosis and Countermeasure Selection tools could be used as part of a safety evaluation to assess the quantitative safety impacts of project design exceptions and decisions, and to identify additional mitigation strategies that may be needed to reach a mutually supportable goal in terms of crash reduction. These strategies could then be incorporated into project design or traffic control plans.

Stage 5: Construction. Construction of the project occurs after contract award (*Associated ADOT Business Unit: Roadway Engineering – Construction Group*).

Relevant *SafetyAnalyst* modules for this stage include the following:

- **Module 2: Diagnosis and Countermeasure Selection Tools.** The Diagnosis and Countermeasure Selection tools could be used to evaluate the safety impacts of any changes made to the design or traffic control plans during the construction process.

Stage 6: Maintenance. Maintenance and operation of the project begins after the constructed project is completed and formally accepted. ADOT's Planning to Programming (P2P) process includes a method for monitoring and assessing the crash reduction benefits resulting from infrastructure improvements. This activity would be supported by TSS, which also would monitor for crash hot spots and identify and recommend countermeasures to reduce crash frequency and/or severity at locations where safety issues have been identified (*Associated ADOT Business Unit: Maintenance, Multimodal Planning Division – Transportation Planning, Roadway Engineering – Traffic Safety Section*).

Relevant *SafetyAnalyst* modules for this stage include the following:

- **Module 1: Network Screening Tool.** The Network Screening tool could be used to identify sites with higher-than-expected crash frequencies or high proportions of specific crash types as part of ADOT's ongoing overall highway safety management system.
- **Module 2: Diagnosis and Countermeasure Selection Tools.** These tools could be used to identify crash contributing factors, crash types, and possible countermeasures for high-crash locations as part of ADOT's ongoing overall highway safety management system.
- **Module 3: Economic Appraisal and Priority Ranking Tools.** The Economic Appraisal and Priority Ranking tools could be used to conduct a benefit-cost analysis to compare safety benefits among various projects and assist ADOT in setting priorities for safety countermeasures across a network as part of their ongoing overall highway safety management system.
- **Module 4: Countermeasure Evaluation Tool.** The Countermeasure Evaluation tool could be used to conduct before/after evaluations of implemented safety improvements once they have been in operation long enough to yield three to five years of crash data. The results could be used to document the benefits of ADOT's safety improvement program and provide better estimates of the effectiveness of specific countermeasures for use in future project scoping and programming activities.

Table 26 summarizes how the different *SafetyAnalyst* modules could be used in ADOT's project development process. This table represents a long-term implementation of *SafetyAnalyst*; initially, network screening will likely be the most commonly used module.

Table 26. Application of *SafetyAnalyst* Modules in the ADOT Project Development Process

Project Development Process Stage	Associated ADOT Business Units	*SafetyAnalyst* Module 1: Network Screening Tool	2: Diagnosis & Counter-measure Selection Tool	3: Economic Appraisal & Priority Ranking Tool	4: Counter-measure Evaluation Tool
Stage 1: Long-Range Planning	Multimodal Planning Division – Transportation Planning	X	X		
Stage 2: Project Scoping	Roadway Engineering – Roadway Predesign and Review Section Traffic Safety Section	X	X	X	
Stage 3: Programming	Multimodal Planning Division – Transportation Programming			X	
Stage 4: Project Development/ Design	Roadway Engineering – Roadway Design		X		
Stage 5: Construction	Roadway Engineering – Construction Group		X		
Stage 6: Maintenance	Maintenance, Multimodal Planning Division – Transportation Planning Roadway Engineering – Traffic Safety Section	X	X	X	X

Preliminary *SafetyAnalyst* Integration Options

Preliminary options for integrating *SafetyAnalyst* into standard business practices at ADOT include the following:

- Option 1: Implementation limited to the traffic safety business unit as a whole. This option would be limited to users within the central office.
- Option 2: Implementation limited to key users (one or two planners/engineers) within associated business units. This option could include users in the central office only, or in both the central office and districts. In the long term, this also could include MPOs.
- Option 3: Systemwide implementation for all staff within associated business units. This option could include users in the central office only, or in both the central office and districts. This also could include MPOs and other cities over the long term, concurrent with integrating all public roads in the model.

Table 27 presents the strengths/weaknesses of each integration option relative to ADOT planning and programming practices, training needs, consistency of use, model integrity, and level of effort required by the ADOT ITG.

Table 27. Preliminary *SafetyAnalyst* Integration Options

Consideration	Option 1	Option 2	Option 3
Integration of Safety into Non-Safety-Specific Planning and Programming	This option would result in the lowest integration of safety into ADOT planning and programming processes, as safety knowledge and application would be limited to TSS. The TSS would be responsible for promoting safety and work on safety analyses for all project activities.	Provides potential for safety to be integrated into activities other than safety-specific activities. Train key staff with interest in safety to begin spreading use of the model.	Provides greatest potential for quantitative safety integration; however, ADOT has the least control of application of the tools.
Training Needs	Training needs would be limited to a few staff. This option would result in limited redundancy in the event of staff changes/ turnover; therefore, there would be potential peaks and valleys in model application.	Moderate training needs. Nonsafety staff may not use the model on a regular basis, so periodic training would be required. Training could be supplemented with summary guides and guidelines/policies regarding use of the model.	Greatest training and monitoring requirements – would require extensive training to ensure users are applying the software and interpreting results correctly.
Consistency of Use	SA expertise would be developed within the TSS, with strong consistency in analysis methods and results.	Consistent application of the model may decline as more staff use the model –issue could be mitigated by limiting access to particular modules within the model.	Consistent application of the model may decline as more staff use the model. Consistency issue could be mitigated through extensive, ongoing user training.
Model Integrity	Highest degree of model integrity, since higher likelihood that users would be working with most recent traffic, crash, and roadway datasets.	Would require slightly more careful management of the model and user versions. Would be mitigated by issuing a new version of the model each year.	Would require ongoing careful management of user versions. Could be mitigated by issuing a new version of the model each year.
ITG Level of Effort	Software and database maintained by ITG. Access to the SA database and analysis module limited to users within the TSS.	Software maintained by ITG, with access to the SA database and analysis module limited to key users within associated business units. Would require moderate coordination and collaboration with users regarding user support, data updates, software version updates.	Software maintained by ITG, and access to the SA database and analysis module would be allowed by all staff in associated business units. Would require extensive coordination and collaboration with users regarding user support, data updates, software version updates.

Initially, ADOT should focus on bringing TSS staff up to a level of expertise that allows for easy use of the model on safety-specific projects. As this expertise grows, TSS staff should begin working to expand the number of model users and expand deployment of the model outside of safety-specific project planning and programming.

Recommended *SafetyAnalyst* Implementation

Developing the Model

It is recommended that ADOT address the gaps and action items identified in Chapter 5 to develop a fully functional *SafetyAnalyst* model. Initially, the model should be developed for all roadway segments under state jurisdiction. At the highest level, the major activities needed will be to create the *SafetyAnalyst* Working Group (staff from TSS, ITG, and TEG) and assign the roles of SA Data Administrator and SA Application Administrator to selected ITG staff members. These staff members will work together closely to complete the activities already identified.

The model should be developed and deployed incrementally in the following order:

- Phase 1: State Roadway Segments – Modules 1 to 3
- Phase 2: State Intersections – Modules 1 to 3
- Phase 3: State Ramp – Modules 1 to 3
- Phase 4: All state roads – Modules 1 to 4
- Phase 5: All public roads – Module 1 to 3 and finally Module 4

The project team's recommendations for how ADOT can fill data gaps with actual values and with assumed data values that will allow the analytical tool to operate are detailed in Chapter 5.

Concurrent with the Phase 1 model development, ADOT Traffic Safety Section staff should prepare to lead the efforts to validate the completed model (entire database schema used for all analytical routines), apply the model, and train themselves and other model users. The major implementation activities for Phase 1 are:

- Developing a validation plan for confirming familiarity with each phase of the model
- Developing a phasing plan for model applications within TSS, other units within ADOT, and, in the future, MPOs
- Developing marketing and training programs
- Developing deployment plans for each additional phase of the model

Preliminary activities recommended for the Working Group are listed in Table 28.

Table 28. Preliminary *SafetyAnalyst* Working Group Activities

Gap	Resolution	Action
People/ Organization Gap	*SafetyAnalyst* Working Group	Create group of SA Application Administrator, SA Data Administrator, and one or two SA end users
	SafetyAnalyst Data Administrator (Data Management Tool)	Nominate a database expert from ITG
	SafetyAnalyst Application Administrator (Administrator Tool)	Nominate a systems expert from ITG
SA Network		• Select elements of the network for SA implementation • State: Segments, intersections, ramps on freeways arterials and collectors • Nonstate: Segments, intersections, ramps on freeways arterials, and collectors
Data		Collect/compile data in order of network priorities consistent with recommendations in Table 9
Application Gap	ETL Script	Create a script to pull data from the source location and analyze, translate, and transform into the SA loading template
	GIS Data Review Tool	Create an ArcGIS Server site with the source data, the SA loading data, and the analytical tool output for investigation and exploration by the end user
Database/System Gap	*SafetyAnalyst* SQL	Create an SQL Server database within an existing SQL Instance
Hardware Gap	Database Server	Create an SQL Server database within an existing SQL Instance
	File Distribution Location	Create an ftp site location or a file server location accessible to all SA users
Workflow/ Process Gap	Preprocessing	Create automated ETL scripts to enable routing populate of SA loading data
	Annual update	Create automated ETL scripts to enable routing populate of SA loading data
	Enterprise distribution	Create a SQL Server database within an existing SQL Instance
	Data/system changes	Create SA Working Group to review data and processes

Validate Completed Model

A validation should be conducted for each phase and for the completed model to ensure that *SafetyAnalyst* is processing the input data records correctly. This can be done by comparing the preprocess and postprocessed data for various network descriptive elements, such as number of roadway segments, number of intersections, number of ramps, and number of crashes by segment. Ensuring that all values in the database are populated with a value will minimize the number of data records rejected by *SafetyAnalyst*.

Applying the Phase 1 Model

In the near term (next three to five years), TSS staff should prepare to be largely responsible for using the model, demonstrating the value of the model, and teaching others to use the model. As TSS staff gain experience with the model, they should strive to identify additional users in the following order: other central office staff, district office staff, and MPOs.

The *SafetyAnalyst* modules that should be deployed are the following:

- **Module 1: Network Screening –** Complete and distribute Phase 1 network screening results to district staff and MPOs if interested. Work with recipients to integrate the results of the model into the HSIP project selection process. Consider working with new users to develop incentives for using *SafetyAnalyst* results. One incentive could be to modify the HSIP project selection processes to add points to projects identified through the *SafetyAnalyst* process. TSS also could begin working to integrate network screening results into non-safety-specific projects as presented in Table 26.
- **Module 2: Diagnosis and Countermeasure Selection –** As district staff become more confident and comfortable with applying the model, begin teaching users how to diagnose safety issues or select countermeasures using *SafetyAnalyst* Module 2. Develop TSS expertise and work with individual project planners, traffic engineers, and designers to use *SafetyAnalyst* diagnosis and countermeasure selection tools. This will likely be on a case-by-case basis and, in the near term, conducted entirely by TSS staff. However, the longer-term vision should be for traffic engineers and designers to use the model for these activities.
- **Module 3: Economic Appraisal and Priority Ranking –** As users conduct more analysis within the model, there will be more opportunity for potential countermeasures to be evaluated and prioritized within *SafetyAnalyst*. As the model becomes more institutionalized, this could become a valuable approach for TSS to work with other DOT staff and MPOs to improve the efficiency of safety investments. As a goal, TSS could work to help all district and/or MPO staff to use the Module 3 tools for developing HSIP programs.
- **Module 4: Countermeasure Evaluation –** In the long term, as projects are deployed and entered into the *SafetyAnalyst* databases, Module 4 could be used to support safety effectiveness evaluations. It is anticipated that this will be one of the last modules deployed and that deployment is not likely until after *SafetyAnalyst* has been extensively used and institutionalized by ADOT.

Develop Marketing and Training Programs

Throughout the development and deployment of the model, TSS will be responsible for training ADOT staff on the appropriate use of the *SafetyAnalyst* tool. In some cases, the training will be limited to teaching users how to interpret and apply the outputs/results from *SafetyAnalyst*. In other cases, TSS will teach users how to use the software and how to interpret and apply the results. The training plan should be phased in according to the modules being applied and the business units potentially applying the model. Table 29 presents a proposed phasing plan for training. This training plan assumes ADOT intends to integrate *SafetyAnalyst* into safety and non-safety project types.

Table 29. Recommendations for *SafetyAnalyst* Training at ADOT

ADOT Business Unit	Module 1: Network Screening Tool	Module 2: Diagnosis & Countermeasure Selection Tool	Module 3: Economic Appraisal & Priority Ranking Tool	Module 4: Countermeasure Evaluation Tool
Traffic Safety Section	A – Using the software	B – Using the software	C – Using the software	D – Using the software
MPD – Transportation Planning	B – Results only	C – Using the software		
Roadway Engineering – Predesign	B – Results only	C – Using the software	D – Using the software	
MPD Transportation Programming			D – Results only	
Roadway Engineering – Design		C – Using the software	C – Using the software	
Construction		D – Using the software		
District Design	B – Results only	C – Using the software		
District Traffic Engineers	B – Results only	C – Using the software		
MPOs	C – Results only	D– Using the software		

A = first priority; B = second priority; C = third priority; D = last priority

Resources that could be useful as part of a training or internal marketing program include:

- Developing guidelines for analyzing the safety benefits of design exceptions and pavement preservation projects
- Developing summaries identifying how *SafetyAnalyst* can be used in typical projects for any given business unit
- Developing white papers, one-page summaries, or examples of typical district or central office projects that used *SafetyAnalyst* in the project development/decision-making process
- Developing an on-line list of frequently asked questions (FAQ) and sample outcomes to support working with the software
- Developing training tailored to typical business units

Phased Model Development Program

Even as Phase 1 of the model has been developed and early application and deployment is underway, the SA Working Group should begin to develop a plan for enhancing the Phase 1 model or beginning development of the Phase 2 model. Enhancements will address the data gaps, application gaps, and database or hardware gaps. Selection of the gaps to address will, of course, be directly related to how closely the model is integrated into the HSIP process and the state project development process. As more state and MPO users take advantage of the model, more needs associated with enhancing the model will arise. Again, it is anticipated that the first three to five years of development and deployment will be focused on the roadway segment network screening module. Until this module is well used within the DOT, it is recommended that ADOT's SA Working Group focus on enhancing the data associated with this module, demonstrating the value of the model with ADOT-specific case studies, and providing training for staff.

Deploying and enhancing the model will require continuous investment in the model. The SA Working Group should be multidisciplinary and must include champions and staff with specific responsibility from ITG, TSS, and other business units such as MPD and TEG. At a minimum, ITG and TSS staff should be involved on an ongoing basis if the model is to be successfully developed and deployed. In order to establish this ongoing commitment, ITG and TSS will need to consider and identify opportunities for ongoing staff availability and a funding stream. In addition to annual *SafetyAnalyst* licensing fees, there may be expenses associated with such items as data needs, training and marketing, state or national travel for training, and user activities. Depending on ADOT culture and staff management programs, ITG and TSS business unit leaders may consider including *SafetyAnalyst* deployment and integration as a performance measure in annual performance responsibilities of staff on the SA Working Group.

Finally, the SA Working Group should strive to maximize the value of the model with the least effort and time. While the model must, of course, be valid to be useful, it need not be perfect before staff can start learning about its potential value to ADOT. It is important to recognize that the model may never be perfect. Instead of waiting to deploy the model until it has the best, most complete data, the best, most precise assumptions about different traffic engineering considerations, or the best, most efficient ETL scripts, it may be more beneficial to deploy an incomplete yet functional model that can demonstrate the value of integrating safety into project activities and enhance the HSIP process.

CHAPTER 7. RECOMMENDATIONS FOR DATA INTEGRATION AND MANAGEMENT

This chapter provides recommendations for data integration and management using ADOT's approved technology stack. The recommendations are intended to provide ADOT with the information needed to implement *SafetyAnalyst* and include recommendations for overall system enhancements and for populating the *SafetyAnalyst* database for distribution and use.

Ideal Condition for *SafetyAnalyst* Implementation

The overall ideal condition for implementation is identified in Chapter 4, where Figure 5 shows in red the necessary changes from the existing condition. Ideally, implementing *SafetyAnalyst* requires an enterprise environment for data storage and distribution using a Microsoft SQL Server for centralized storage and dissemination of calibrated *SafetyAnalyst* data; this approach reduces the risk of outdated data and eliminates multiple data copies across the network. To facilitate the enterprise distribution model at ADOT, several gaps must be filled (as stated in Chapter 5). Requirements for filling these gaps are outlined below.

Required Changes in Systems and Workflow

- **Filling Database/System Gaps**
  - *SafetyAnalyst* (SQL): ADOT needs to create and use an SQL Server database for the distribution of postprocessed *SafetyAnalyst* data.
    - Users need read-only access and sufficient network connectivity to use this resource.
    - The database requires an administrator for performance, connectivity, credentials, and process management.
- **Filling Hardware Gaps**
  - Database Server: Identify an existing enterprise SQL Server Database Server for the storage and distribution of postprocessed *SafetyAnalyst* data.
    - This will be the distribution point for SA information and will prevent *SafetyAnalyst* data packages from being distributed across ADOT as individual Derby databases.
    - ADOT could use a new SQL Database Server, but the load required by *SafetyAnalyst* does not justify this expense. Any existing SQL implementation with appropriate connectivity and available load will suffice.
  - File Distribution Location: Identify an existing location for the distribution of the *SafetyAnalyst* install package (without data) that points to the SQL Database Server. This file is produced by *SafetyAnalyst* after postprocessing and will be downloaded by users for local installation and use of *SafetyAnalyst* postprocessed information (Analytical Tool).

- **Filling Workflow/Process Gaps**
    - Enterprise Distribution: Use SQL Server instead of individual Derby databases for data storage and distribution, thus eliminating data publication and version issues and discrepancies.
    - Data/System Changes: Add a process to make changes to the data/systems, and then review how the changes affect users and the analytics of *SafetyAnalyst* outputs. ADOT should formalize this process and use the SA Working Group to make decisions and test impacts before implementing changes fully.

Required Changes in Organization and Staffing

- **Adding a *SafetyAnalyst* Working Group**
    - The SA Working Group will make critical decisions regarding *SafetyAnalyst* data inputs, assumptions, transformations, and quality control as the data and systems evolve.
    - The group should be small and should represent the interested parties within ADOT and the user community.
    - The group will be responsible for discussing and testing the ramifications of changes to tool operation, data input sources, assumptions, and any other potential change to the overall system.
    - The SA Data Administrator and the SA Application Administrator should participate in this group.
- **Assigning a *SafetyAnalyst* Data Administrator (Data Management Tool)**
    - The assigned administrator will be responsible for the Data Management Tool and should be an IT/database resource familiar with the data and data requirements for SA.
    - This individual will be responsible for all data preprocessing activities (including future ETLs), loading data into *SafetyAnalyst*, and postprocessing the *SafetyAnalyst* database.
    - This employee will be responsible for implementing any changes in data sources, assumptions, or analytical techniques.
    - This individual should participate in the SA Working Group.
- **Assigning a *SafetyAnalyst* Application Administrator (Administrator Tool)**
    - This assigned administrator will be responsible for the Administrator Tool and should be an IT resource familiar with the workflow and distribution requirements for *SafetyAnalyst*.
    - This individual will be responsible for product licensing, the overall systems involved (SQL Server, file distribution, ETL management, user management, and publication management), and the system's overall upkeep.
    - This individual should participate in the SA Working Group.

Implementation Strategy

To successfully implement an enterprise *SafetyAnalyst* deployment, ADOT should perform the following:

- Develop conceptual design (systems)
- Identify software/hardware locations
- Develop a *SafetyAnalyst* data model
- Develop data import schema
- Perform initial data creation procedures
- Prepare roadway segment, crash record, and segment traffic data
- Load SafetyAnalyst
- Create *SafetyAnalyst* Installer

These activities are discussed in more detail in the following sections.

Develop Conceptual Design (Systems)

At its core, *SafetyAnalyst* is composed of three software tools (Administration, Data Management, and Analytical) and two core databases (System Data and Calibrated Distribution Data). The Analytical tool and the Calibrated Distribution Database are the access points for end users and analysts, while the Administration and Data Management tools and the System Database are predominantly for IT and database administrators.

Administration Tool. This tool is used to set up and manage the *SafetyAnalyst* deployment. It enables an agency to tailor the *SafetyAnalyst* data model and to modify the federally supplied default data used in conducting safety analyses.

Data Management Tool. This tool is used to import and prepare an agency's inventory, traffic volume, and accident (crash) data for analysis. In the current release, a separate application is provided to manage the set of countermeasures that have been applied to an agency's inventory.

Analytical Tool. This tool is used to conduct safety analyses of an agency's inventory. To ensure data integrity, this client application accesses the agency data in a read-only mode.

Identify Software/Hardware Locations

ADOT ITG needs to identify and establish a permanent location for the Administration Tool, the Data Management Tool, a Derby data preparation database (preprocessing), and a SQL Server database for distribution. The Analytical Tool will be installed locally for each user. Each of these tools and databases is discussed below.

Administration Tool Location. The Administration Tool is used to administer the agency data, federal defaults, and system data. This tool should reside in the same location as the Data Management Tool, because the preprocessing and postprocessing routines need access to the agency, federal, and system data. This location also will need access to (or create) the Derby database for data loading, preprocessing, postprocessing, and calibration. The identified location can be an enterprise server for multiuser access or a stand-alone Microsoft Windows PC. In either scenario, the machine will be required to support Java programming language and JDBC.

Data Management Tool Location. The Data Management Tool is an application used to create, preprocess, postprocess, and calibrate *SafetyAnalyst* data. This tool should reside in the same location as the Administration Tool, because the preprocessing and postprocessing routines need access to the agency, federal, and system data. This location also will need access to (or create) the Derby database for data loading, preprocessing, post processing, and calibration. The identified location can be an enterprise server for multiuser access or a stand-alone Microsoft Windows PC. In either scenario, the machine will be required to support Java programming language and JDBC.

Derby Database Location. The Derby database will reside in the file structure of the identified location on the computer where the Administration and Data Management tools reside. The identified location will support multiple Derby databases, one for each instance of *SafetyAnalyst* data. Each Derby database tends to be small (well under a gigabyte); therefore, hard drive size considerations are negligible.

SQL Server Distribution Database Location. A SQL Server instance should be identified or created to store and distribute final *SafetyAnalyst* data to the enterprise. The SQL Server instance can reside on any server within the network that the necessary users can access. End users will require read-only access to the database and data tables. The hard drive space required to support the *SafetyAnalyst* database is negligible. Computer memory and processor speed also are not of great concern to the overall *SafetyAnalyst* implementation.

Analytical Tool Location. The Analytical Tool will be installed locally for each end user of the system. Upon installation, local flat files are created for user preferences, analysis results, and reports for each user on the computer hard drive. This is true for ADOT end users and non-ADOT end users as they may be included over time.

Develop a SafetyAnalyst Data Model

The *SafetyAnalyst* data model is documented very well in the Data Management Tool Manual provided with the software and, therefore, is not documented here. However, *SafetyAnalyst* does allow for certain changes to the default schema and default schema values, and these changes are managed in the Agency Overrides database (Derby database) local to the Administration Tool install location.

The Agency Overrides database can be altered using the Administration Tool on the Edit tab. On the Edit tab (Figure 7), the *SafetyAnalyst* administrator can permanently change certain deployment attributes, site subtypes, user permissions, countermeasures, diagnostics, distributions, SPFs, and EAPRM parameters.

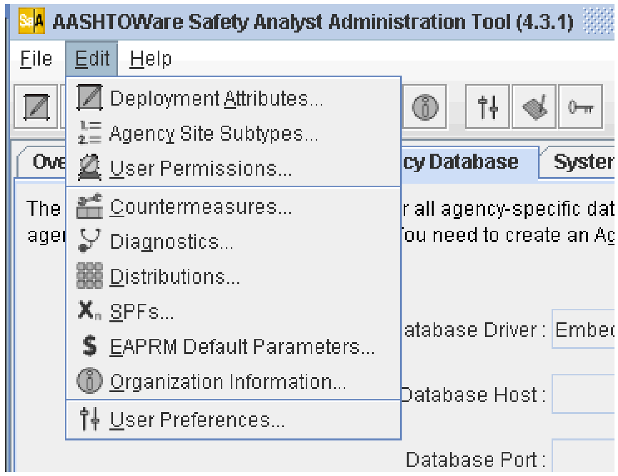


Figure 7. The Edit Tab of the Administration Tool

Not all elements in *SafetyAnalyst* can be altered through the Administration Tool. Most elements within *SafetyAnalyst* are required or are hard-coded into the software and, therefore, cannot be changed. Any changes made within the Administration Tool should be done before loading, preprocessing, postprocessing, and calibrating data. Data elements can be altered directly in the Administration Tool interface or through an export/import process using .xml files. Both methods of editing are acceptable. The .xml export/import can be faster; however, the editor must be very careful editing the .xml. The requirements for loading the edited values correctly (so that *SafetyAnalyst* can access the information) are very precise.

Develop Data Import Schema (three .txt files)

For data to be loaded into *SafetyAnalyst*, the input data must be converted or aggregated into the data loading schema and converted to a .csv (or .txt) file. The data import schema for altRoadwaySegment (roads), altAccident (crashes), and altSegmentTraffic (volume data) are shown in Tables 30, 31, and 32, respectively.

Table 30. altRoadwaySegment Schema

Column Name	Data Type	Column Name	Data Type
agencyID	String	d2avgLaneWidth	Double
locSystem	String	medianType1	String
routeType	String	medianWidth	Double
routeName	String	d1shoulderTypeOut	String
county	String	d1shoulderTypeIn	String
startOffset	Double	d2shoulderTypeOut	String
endOffset	Double	d2shoulderTypeIn	String
agencySiteSubtype	String	d1avgShoulderWidthOut	Double
gisID	String	d1avgShoulderWidthIn	Double
altRouteNames	String	d2avgShoulderWidthOut	Double
majorRoadName	String	d2avgShoulderWidthIn	Double
segmentLength	Double	accessControl	String
district	String	drivewayDensity	Double
city	String	growthFactor	Double
jurisdiction	String	postedSpeed	Double
areaType	String	operationWay	String
terrain	String	travelDirection	String
roadwayClass1	String	increasingMilesposts	String
d1numThruLane	Integer	d1bikeway	String
d2numThruLane	Integer	d2bikeway	String
d1auxLane1	String	interchangeInfluence	String
d1auxLane2	String	openedToTraffic	Date
d1auxLane3	String	discontinuity	String
d2auxLane1	String	corridor	String
d2auxLane2	String	comment	String
d2auxLane3	String	accessKey	String
d1avgLaneWidth	Double		

Table 31. altAccident Schema

Column Name	Data Type	Column Name	Data Type
agencyID	String	schoolBus	String
locSystem	String	workZone	String
routeType	String	numVehicles	Integer
routeName	String	drugInvolved	String
county	String	towIndicator	String
locSection	String	runoffIndicator	String
locOffset	Double	pedestrianIndicator	String
gisID	String	bikeIndicator	String
accidentSegmentID	String	sideOfDividedHighway	String
accidentIntersectionID	String	v1initialTravelDirection	String
accidentRampID	String	v2initialTravelDirection	String
accidentDate	Date	v1vehicleManeuver	String
accidentTime	String	v2vehicleManeuver	String
accidentSeverity1	String	v1vehicleConfiguration	String
numberOfInjuries	Integer	v2vehicleConfiguration	String
junctionRelationship	String	v1firstEvent	String
drivewayIndicator	String	v2firstEvent	String
lightCondition	String	v1driverDOB	String
weatherCondition	String	v2driverDOB	String
surfaceCondition	String	comment	String
collisionType	String	numberOfFatalities	Integer
environmentCondition	String	JoinFieldTemp	Integer
roadCondition	String		

Table 32. altSegmentTraffic Schema

Column Name	Data Type
agencyID	String
calendarYear	Integer
aadtVPD	Double
percentHeavyVehicles	Double
peakHourlyVolume	Double
comment	String

Perform Initial Data Creation Procedures

The initial data creation procedures for *SafetyAnalyst* are the same procedures used to update *SafetyAnalyst* with new data or to replace *SafetyAnalyst* data with revised data, as shown in Figure 8. The overall procedures use GIS to aggregate and assign a common reference, and then use any data editing application (e.g., ArcGIS, Microsoft Access, Microsoft SQL Server) to translate data values. The *SafetyAnalyst* Data Management Tool is then used to import data, preprocess, postprocess, and calibrate. Recommendations for this process are as follows:

- Use the local Derby database for initial data creation procedures to minimize connectivity and application-related errors during the loading process. Once the data are error-free, then the data should be loaded into SQL Server for distribution.
- Alter or create any Agency Overrides in the Administration Tool before the import files are created and loaded.
- Use GIS and LRS to generate a common, standard location reference for each data element. *SafetyAnalyst* uses tabular data to reference and analyze roads, crashes, traffic, and countermeasures.

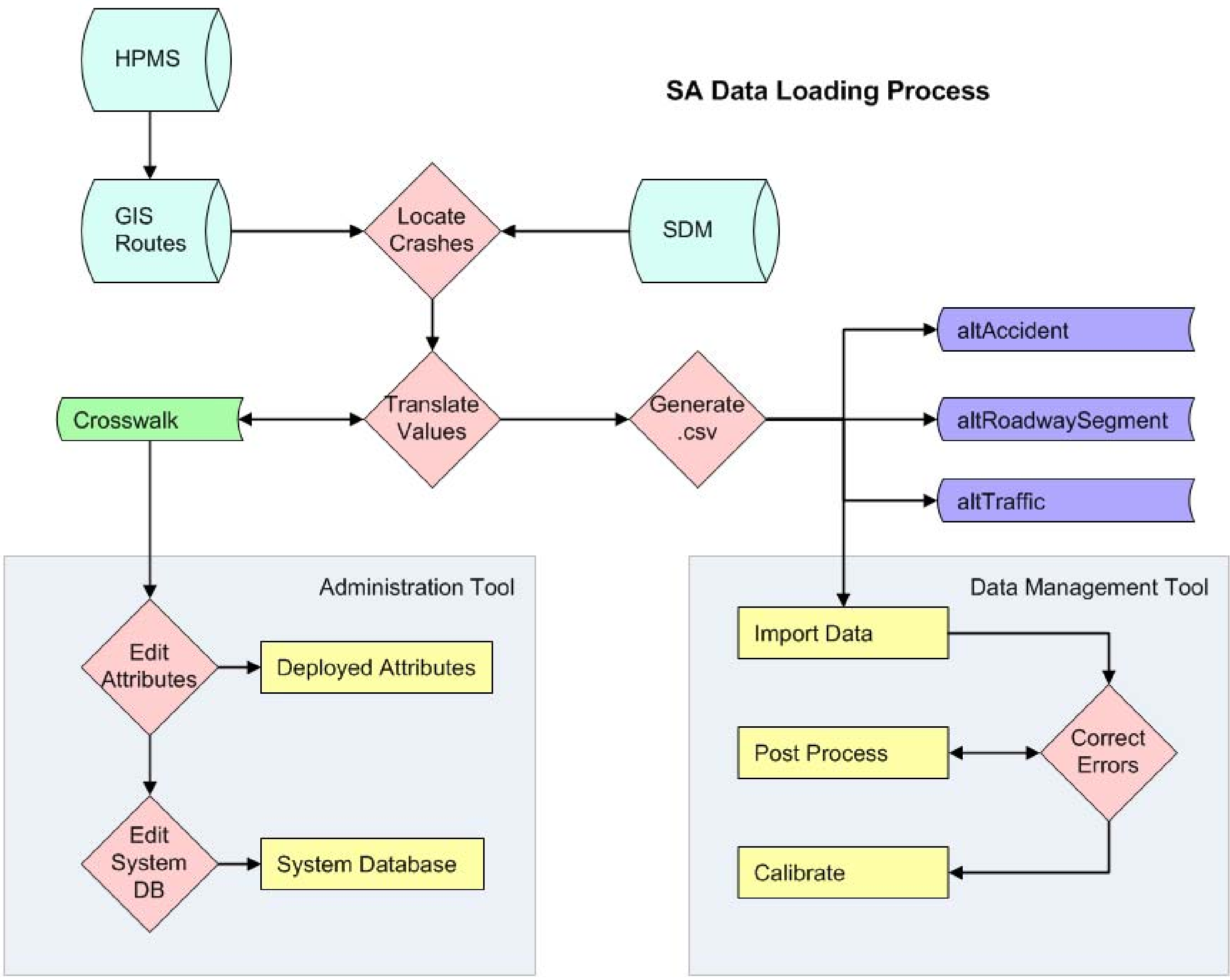


Figure 8. *SafetyAnalyst* Data Loading Process Overview

Source: ARCADIS-generated graphic.

Prepare Roadway Segment Data (altRoadwaySegment)

Note: The traffic segment preparation values should be included in the roadway segment value preparation so that both result sets have the same segmentation and identifiers. This process should be performed only once for the entire required dataset.

Segment Identification. The first step in roadway segment preparation is to select or identify the desired input roadway segments (all roads, State Highway System, Functionally Classified, etc.). These records should be pulled from the GIS LRS and exported to an off-line geodatabase for further processing. Note: The off-line geodatabase will provide a static route network free from changes during the data creation process. Each roadway segment record should have a route ID (ATIS Code) and a beginning and ending measure value.

For each roadway segment record, data values must be assigned for all data elements identified in the altRoadwaySegment import schema. If any value for any record is left blank or null, that record will be rejected by *SafetyAnalyst* in the loading process. Note: It was found in the pilot project that, although "unknown" values are acceptable for loading, a record with an "unknown" value is likely to be rejected during postprocessing. Therefore, it is recommended that any "unknown" values be replaced with an educated guess or best judgment based upon ADOT standards. These judgments can be recorded and subsequently refined as resources become available.

Data Input Identification. Each data element to be populated in the import schema should be identified in the linear events in the GIS LRS. Each event in the LRS has a route ID and a beginning and ending measure that correspond to the location on the route network. Each identified data element must be overlaid on the route network and subsequently grouped together to create distinct roadway segments with all of the needed input values.

Input Data Overlay. Several GIS geoprocessing tools can be used to achieve the desired result. Given the structure of the new LRS at ADOT (August 2014), the Overlay Route Events tool is recommended. This tool performs an intersect of input event layers that results in records with homogeneous attribute values. Every change in attribute along the route results in a segment break. Therefore, great care should be taken to minimize undershoots, overshoots, and overlaps in the input data. Each individual data element should be intersected or overlaid with the route network using this tool until all the necessary *SafetyAnalyst* roadway segment values are aggregated into one dataset with breakpoints at each attribute change.

It is expected that precision or accuracy errors in the input data may produce numerous slivers or very short segments. *SafetyAnalyst* rejects very short segments, as these short segments can skew overall analysis results. Any cleanup activities that can be performed at this point will reduce the number of load warnings during *SafetyAnalyst's* load process. To clean up sliver segments, the Dissolve geoprocessing tool can be used against certain input data values. The dissolve function collapses records with the same value in the dissolve attribute (or multiple attributes). Care should be taken in dissolve attribute selection, as most of the splits in data records reflect the desired result; the dissolve should only collapse records with erroneous splits caused by data accuracy issues. If this is a pervasive problem, one solution could be to define *SafetyAnalyst* segments as an input event, thus providing the dissolve attribute of SegmentID and allowing the data manager to easily dissolve the output records. Over time, this is likely to become less of an issue as overall data accuracy in the GIS improves.

Measure Assignment. Once the overlay is complete, a beginning and ending measure must be assigned to each individual segment. (Note: All input events have beginning and ending measures; however, the overlay process segments most, if not all, inputs—the segmentation nullifies the existing measure values and requires that the values be reassigned.) The first geoprocessing tool in this process is the Feature Vertices to Points tool. This tool takes the beginning and ending point locations for each input segment and converts these locations to a point feature class. The point feature classes, one for beginnings and one for ends, are then processed with the geoprocessing tool Locate Features Along Routes. This tool assigns the nearest route and measure to each point location. Multiple route and measure locations may be returned for each point—one for every route within the search radius. These results must be joined back to the input dataset so that the input routeID can be compared with the result set routeID. The matching records contain the appropriate measure value for that location along the correct route. The matching record must then be joined back to the original overlay output segment so the true beginning and ending measures for that segment can be assigned. At this point, all of the input overlay events in the dataset are merged into homogenous segments with beginning and ending measure values that correspond to their true locations on the route network.

Value Translation and Assignment. Most of the data values stored within the GIS event layers are not the expected values within *SafetyAnalyst*. These values must be translated from the existing GIS stored values to the *SafetyAnalyst* expected values. For example, the GIS stores Terrain Type as a numeric value (1 – Level, 2 – Rolling, 3 – Mountainous), while *SafetyAnalyst* is expecting a character value (L – Level, R – Rolling, M – Mountainous). Each value requiring translation must be selected and updated to the appropriate *SafetyAnalyst* value. Depending on the data manager's preferred software, numerous methods can be used, including Update Query in SQL Server and Select and Calculate in GIS. The data crosswalk (completed as part of this project and submitted in electronic form to ADOT) details the translation values that are required.

Certain values need direct assignment rather than a translation, as these values are not derived from the event overlay process. These values should be calculated or updated in the resulting dataset. For example, the LocSystem field should be calculated to value "A" – Route/Measure, which tells *SafetyAnalyst* that this record uses a route and measure location methodology for location. The data crosswalk (completed as part of this project and submitted in electronic form to ADOT) identifies the fields that should be assigned values directly.

Note: It was found in the pilot project that, although "unknown" values are acceptable for loading, a record with an "unknown" value is likely to be rejected during postprocessing and will not be available for analysis. Therefore, it is recommended that any "unknown" values be replaced with an educated guess or best judgment based upon ADOT standards. These judgments can be recorded and subsequently refined as resources become available.

Schema Cleanup and .txt File Generation. After all values have been assigned and translated, the dataset must be cleaned of any non-*SafetyAnalyst* schema fields. The loading process for *SafetyAnalyst* results in an error if the input dataset contains extraneous or unexpected columns. Once the dataset is cleaned and ready, the dataset can be exported to a .txt file for final preparation.

SafetyAnalyst expects the input data to be a .txt file that is comma delimited, with the first line being the table name (i.e., altRoadwaySegment), the second line being the column headers, and each subsequent line being the individual data records (Figure 9). It is very important that the table name and the column headers exactly match the *SafetyAnalyst* schema, including capital and lower-case letters. *SafetyAnalyst* produces an error if the input data are not correctly formatted.

```
altRoadwaySegment
agencyID,locSystem,routeType,routeName,county,startOffse
4,A,I,  I 017                         1,13,34.48,36.35,,4,
5,A,L,07  SWEETWATER          AVE,13,18.56,19.03,,5,,,0.
6,A,L,07  28TH                DR,13,20.85,21.35,,6,,,0.4
7,A,I,  I 017,13,16.50,16.97,,7,,,0.46,M,PHX,2,U,X,1,4,4
8,A,I,  I 017                         1,13,36.35,37.39,,8,
```

Figure 9. altRoadwaySegments Example

Note: *SafetyAnalyst* accepts other data loading methodologies that ADOT could explore.

Prepare Crash Record Data (altAccident)

Crash record preparation begins with record selection from the Safety Data Mart or some other acceptable location. All crashes that are loaded into *SafetyAnalyst* also require selection of the vehicle unit data. Selected data should be extracted to an off-line location for processing and preparation to be loaded into *SafetyAnalyst*. Unit information is a required input of the crash and should be joined to the crash record prior to proceeding.

Measure Assignment. Each crash record must be assigned a route and measure that correspond to the same route network that was used in the roadway segment generation. It is critically important that all *SafetyAnalyst* input data use the same reference location information so that each data record correlates appropriately with the other data records in the same physical location.

To assign route and measure, each crash location must be generated spatially using X, Y, or some other method that results in a GIS point location. Each point is then processed with the geoprocessing tool Locate Features Along Routes. This tool assigns the nearest route and measure to each point location. Multiple route and measure locations may be returned for each point; one for every route within the search radius. These results must be joined back to the input dataset so that the input routeID can be compared with the result set routeID. The matching records contain the appropriate measure value for that location along the correct route. The matching record must then be joined back to the original crash record so that the true measure for that crash can be assigned. At this point, all of the input overlay events in the dataset are merged into homogenous segments with beginning and ending measure values that correspond to their true locations on the route network.

Value Translation and Assignment. Most of the data values stored within the crash records are not the expected values within *SafetyAnalyst*. These values must be translated from the existing crash stored values to the *SafetyAnalyst* expected values. Each value requiring translation must be selected and updated to the appropriate *SafetyAnalyst* value. Depending on the data manager's preferred software, numerous methods can be used, including Update Query in SQL Server and Select and Calculate in GIS. The data crosswalk (completed as part of this project and submitted in electronic form to ADOT) details the translation values that are required.

Certain values need direct assignment rather than a translation, as they are not derived from the event overlay process. These values should be calculated or updated in the resulting dataset. For example, the LocSystem field should be calculated to value "A" – Route/Measure, which tells *SafetyAnalyst* that this record uses a route and measure location methodology for location. The data crosswalk (completed and submitted in electronic form to ADOT) identifies the fields that should be assigned values directly.

Note: The pilot project found that, although "unknown" values may be loaded, a record with an "unknown" value is likely to be rejected by *SafetyAnalyst* during postprocessing and will not be available for analysis. It is recommended that "unknown" values be replaced with an educated guess based on ADOT standards. These judgments can be recorded and later refined as resources become available.

Schema Cleanup and .txt File Generation. After all values have been assigned and translated, the dataset must be cleaned of any non-*SafetyAnalyst* schema fields. The loading process for *SafetyAnalyst* results in an error if the input dataset contains extraneous or unexpected columns. Once the dataset is cleaned and ready, the dataset can be exported to a .txt file for final preparation.

SafetyAnalyst expects the input data to be a .txt file that is comma delimited, with the first line being the table name (i.e., altAccident), the second line being the column headers, and each subsequent line being the individual data records (Figure 10). It is very important that the table name and the column headers exactly match the *SafetyAnalyst* schema, including capital and lower-case letters. *SafetyAnalyst* produces an error if the input data are not correctly formatted.

```
altAccident
agencyID,locSystem,routeType,routeName,county,locSection,
2407592,A,I,  I 017                        0 ,MARICOPA,,9.
2409479,A,I,  I 017                        0 ,MARICOPA,,6.
2412162,A,I,  I 017                        0 ,MARICOPA,,0.
2409494,A,I,  I 017                        0 ,MARICOPA,,8.
2412159,A,I,  I 017196J                      ,MARICOPA,,0.
```

Figure 10. altAccident Example

Note: *SafetyAnalyst* accepts other data loading methodologies that ADOT could explore.

Prepare Segment Traffic Data

Ideally, Segment Traffic data are prepared in tandem with the roadway segment overlay so that the segmentation for roadways and traffic are identical. The data manager can perform the preparation steps once for the entire dataset instead of performing them on each dataset and trying to reconcile the two. If the segment traffic data are prepared with roadway segments, then the data manager can skip to the Value Translation and Assignment section.

Data Input Identification. Each data element to be populated in the import schema should be identified in the linear events in the GIS LRS. Each event in the LRS has a route ID and a beginning and ending measure that correspond to the location on the route network. Each identified data element must be overlaid on the route network and subsequently grouped together to create distinct roadway segments with all of the needed input values.

Input Data Overlay. Several GIS geoprocessing tools can be used to achieve the desired result. Given the structure of the new LRS at ADOT (August 2014), the Overlay Route Events tool is recommended. This tool performs an intersect of input event layers that results in records with homogeneous attribute values. Every change in attribute along the route results in a segment break. Therefore, great care should be taken to minimize undershoots, overshoots, and overlaps in the input data. Each individual data element should be intersected or overlaid with the route network using this tool until all the necessary *SafetyAnalyst* roadway segment values are aggregated into one dataset with breakpoints at each attribute change.

It is expected that precision or accuracy errors in the input data may produce numerous slivers or very short segments. *SafetyAnalyst* rejects very short segments as these short segments can skew overall analysis results. Any cleanup activities that can be performed at this point will reduce the number of load warnings during *SafetyAnalyst's* load process. To cleanup sliver segments, the Dissolve geoprocessing tool can be used against certain input data values. The dissolve function collapses records with the same value in the dissolve attribute (or multiple attributes). Care should be taken in dissolve attribute selection, as most of the splits in data records reflect the desired result; the dissolve should only collapse records with erroneous splits caused by data accuracy issues. If this is a pervasive problem, one solution could be to define *SafetyAnalyst* segments as an input event, thus providing the dissolve attribute of SegmentID allowing the data manager to easily dissolve the output records. Over time, as overall data accuracy in the GIS improves, this is likely to be less of an issue.

Measure Assignment. Once the overlay is complete, a beginning and ending measure must be assigned to each individual segment. (Note: All input events have beginning and ending measures; however, the overlay process segments most, if not all inputs—the segmentation nullifies the existing measure values and requires that the values be reassigned.) It is possible that the overlay results will not create additional segmentation or breaks in segments. If this is the case, then this step is not necessary, as the existing measure values can be used. The first geoprocessing tool in this process is the Feature Vertices to Points tool. This tool takes the beginning and ending point locations for each input segment and converts these locations to a point feature class. The point feature classes, one for beginnings and one for ends, are then processed with the geoprocessing tool Locate Features Along Routes. This tool assigns the nearest route and measure to each point location. Multiple route and measure locations may be returned for each point; one for every route within the search radius. These results must be joined back to the input dataset so that the input routeID can be compared with the result set routeID. The matching records contain the appropriate measure value for that location along the correct route. The matching record must then be joined back to the original overlay output segment so the true beginning and ending measures for that segment can be assigned. At this point, all of the input overlay events in the dataset are merged into homogenous segments with beginning and ending measure values that correspond to their true locations on the route network.

Value Translation and Assignment. Most of the values needed for segment traffic do not require translation. Only a few select alterations are required prior to loading into *SafetyAnalyst*. The biggest translation requirement revolves around the calendar year field, as this field should be populated for each data record.

Each traffic segment must have the same segmentation as the roadway segment data. Therefore, the roadway segment IDs must be assigned to each traffic segment in the event that these data were not processed together. If traffic segments were prepared with the roadway segments, then an additional step is required to extract the necessary information from roadway segment data to create the traffic segment file containing only the necessary traffic data elements as defined in the crosswalk.

Note: It was found in the pilot project that all road segments require traffic values. If any roadway segment does not have traffic values, then these values should be collected or estimated and then assigned. Without a corresponding traffic record, *SafetyAnalyst* will not allow analysis of the roadway segment.

Schema Cleanup and .txt File Generation. After all values have been assigned and translated, the dataset must be cleaned of any non-*SafetyAnalyst* schema fields. The loading process for *SafetyAnalyst* results in error if the input dataset contains extraneous or unexpected columns. Once the dataset is cleaned and ready, the dataset can be exported to a .txt file for final preparation.

SafetyAnalyst expects the input data to be a .txt file that is comma delimited, with the first line being the table name (i.e., altSegmentTraffic), the second line being the column headers, and each subsequent line being the individual data records (Figure 11). It is very important that the table name and the column headers exactly match the *SafetyAnalyst* schema, including capital and lower case letters. *SafetyAnalyst* produces an error if the input data are not correctly formatted.

```
altSegmentTraffic
agencyID,calendarYear,aadtVPD,percentHeavyVehicles,peakHour
4,2011,15000.00,10.00,1000.00,
5,2011,10639.00,10.00,2659.75,
6,2011,11703.00,10.00,2925.75,
7,2011,226888.00,10.00,56722.00,
8,2011,15000.00,10.00,1000.00,
```

Figure 11. altSegmentTraffic Example

Note: *SafetyAnalyst* accepts other data loading methodologies that ADOT could explore.

Load SafetyAnalyst

Once all of the input data are prepared, the .txt files are ready to be loaded into *SafetyAnalyst*. The data manager can use the Data Management tool within *SafetyAnalyst* to load data and perform the necessary data processing.

To load data, a data repository (dataset) is required. The data manager can use an existing dataset or choose to create a new one. It is recommended that a new dataset be created each time data are loaded to eliminate the chance of duplicating records or causing corruption within the *SafetyAnalyst* database. When the Data Management tool is opened, the user is immediately prompted to choose a dataset or create a new one (Figure 12). It is recommended that on the initial load, the local Derby database be used until the input data are clean of errors and warnings.

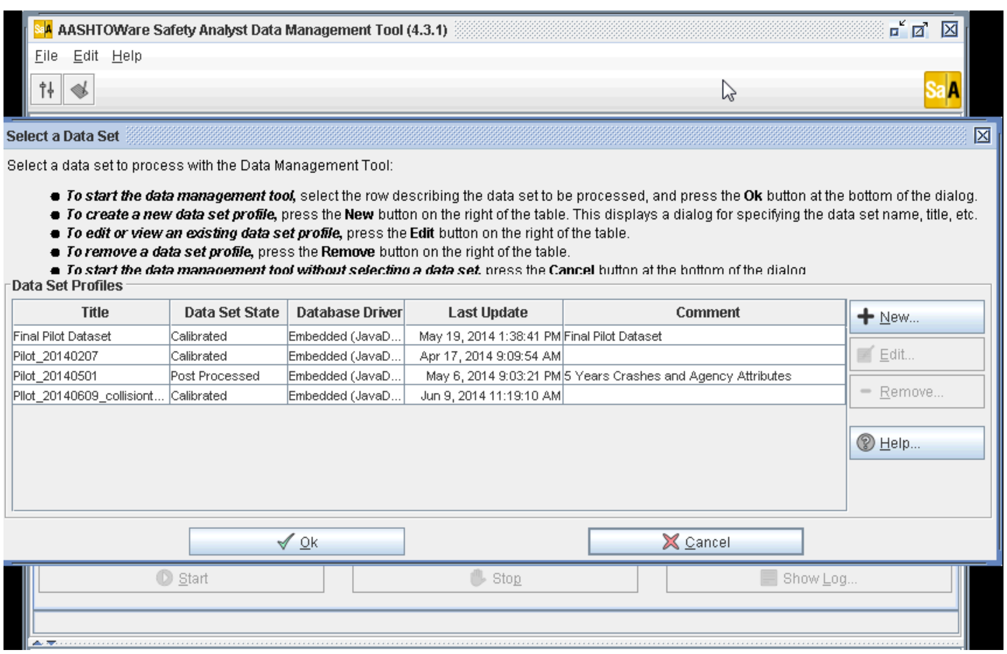


Figure 12. Data Management Tool – Select Data

Once the dataset is created, it is available to be selected for further processing. The first process to be performed is the Import process on the Import tab, as shown in Figure 13. The data manager adds the .txt files generated in the preparation steps from the appropriate location, and then selects the Start Import process. It is recommended that the logging level be set to High until the data manager becomes comfortable with *SafetyAnalyst* and the input data. A thorough review of the import log is recommended, as this log displays all of the errors and warnings generated during the import process. Errors and warnings should be addressed (if necessary) before the postprocessing step begins. If errors can be corrected in the input data, then the data manager should start the overall input process again with the corrected data in a new dataset.

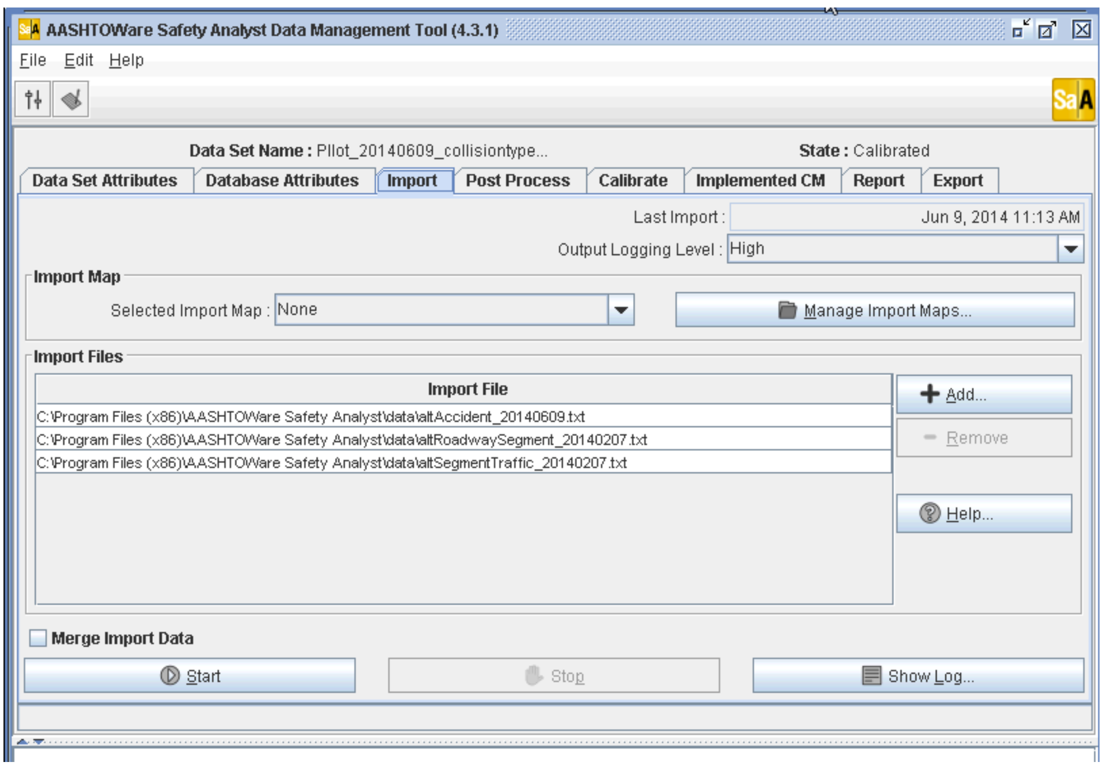


Figure 13. Data Management Tool – Import Data

The second step in the *SafetyAnalyst* loading process is postprocessing. After import, the Post Process tab is populated with some statistical information and user-configurable options. After reviewing this information, the data manager can start the Post Process, as shown in Figure 14. It is recommended that the logging level be set to High until the data manager becomes comfortable with *SafetyAnalyst* and the input data. A thorough review of the Post Process log is recommended, as this log displays all of the errors and warnings generated during the Post Process. Errors and warnings should be addressed (if necessary) before the calibration step begins. If errors can be corrected in the input data, then the data manager should start the overall input process again with the corrected data in a new dataset.

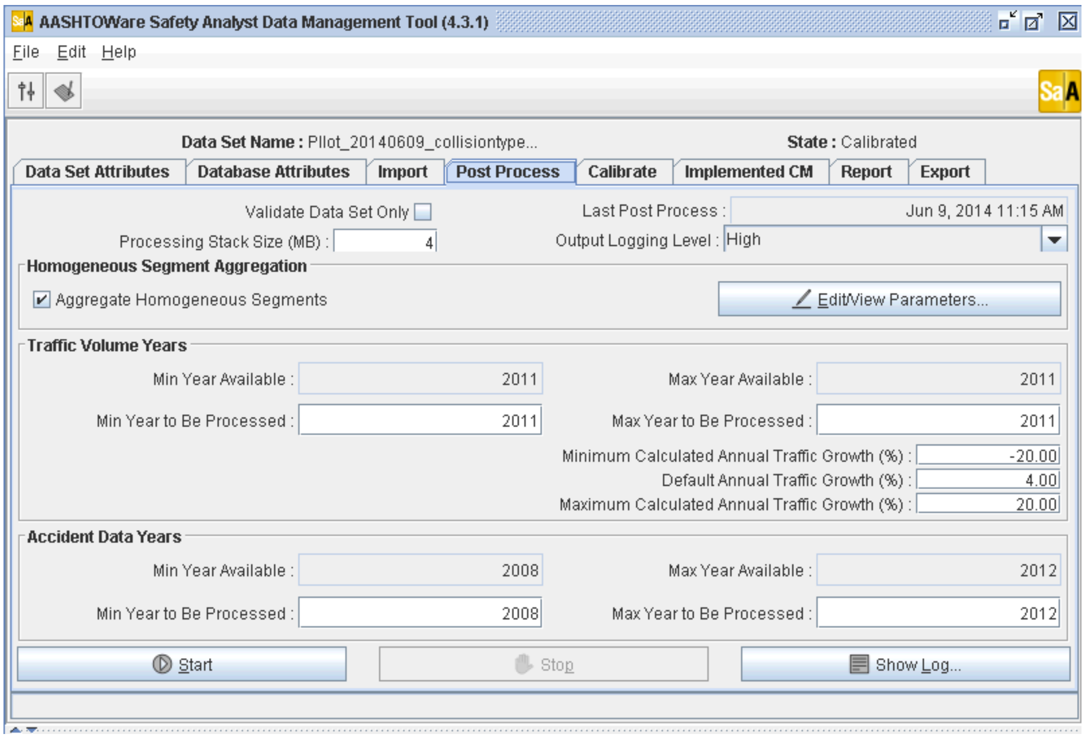


Figure 14. Data Management Tool – Post Process

Calibrating the postprocessed data is the third and final step in the loading process, as shown in Figure 15. The data manager must calibrate the dataset before the dataset is analyzed in the Analytical tool or distributed via the Administration tool. There are minimal calibration parameters to review or verify before starting the calibration. It is recommended that the logging level be set to High until the data manager becomes comfortable with *SafetyAnalyst* and the input data. A thorough review of the Calibration log is recommended, as this log displays all of the errors and warnings generated during the calibration process. Errors and warnings should be addressed (if necessary) before the analysis begins. If errors can be corrected in the input data, then the data manager should start the overall input process again with the corrected data in a new dataset.

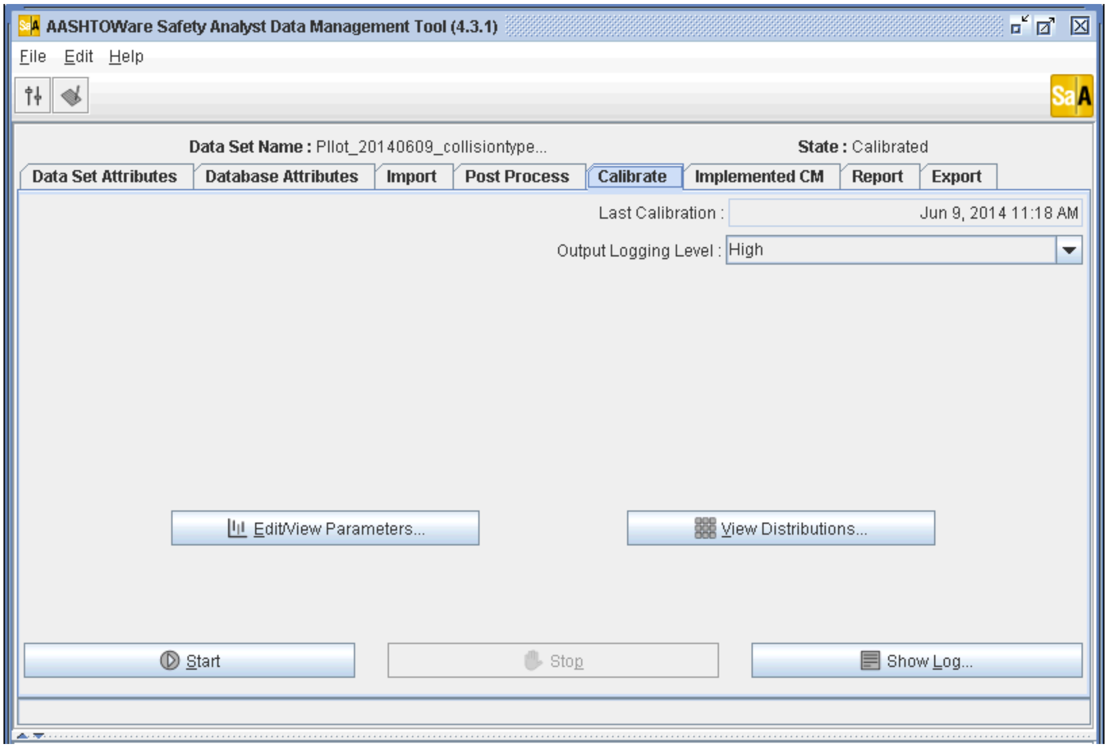


Figure 15. Data Management Tool – Calibrate

After the calibration process, the dataset of imported data can be used in the Analysis tool and can be distributed using the Administration tool.

Once the import data has been cleaned as much as possible to address various *SafetyAnalyst* errors and warnings, the overall import, postprocessing, and calibration process should be run again, using the identified SQL Server instance as the dataset location. This enables the enterprise-level distribution of *SafetyAnalyst* data (without having to distribute the raw data with the *SafetyAnalyst* install file).

Create SafetyAnalyst Installer

The Administration tool is the application used to generate the *SafetyAnalyst* Installer file. To generate an installer file, the data manager opens the Administration tool, navigates to the Create Installer tab, and selects Create Installer. The data manager must identify the final calibrated dataset to be included with the installer. The output of the create installer process is an executable file that is ready for distribution.

CHAPTER 8. FINAL RECOMMENDATIONS

For ADOT to deploy the AASHTOWare *SafetyAnalyst* software requires organizing existing crash, roadway, and traffic volume databases into a large, very specific database that can then be imported into *SafetyAnalyst*. Developing this database will require a team effort from the ITG, TSS, TEG, TRS, and MPD units, as each group has specific expertise needed to organize the data, interpret the data, and review and verify results. Dedicated staff time is needed to make sure the databases are properly related, initial results are validated, and initial deployment is successful. Once the *SafetyAnalyst* model is up and running, the combined team will need to review, update, and maintain the model periodically; however, the frequency required will decrease to once or twice per year. At this point, the team's effort can focus on applying the model and training other staff to use it.

Implementing the software at ADOT is feasible and, once deployed, it will be a valuable tool for highway safety improvement planning and safety project prioritizing. With improved analysis and prioritization there is yet more potential for transportation safety projects to reduce fatalities and serious injuries on Arizona roadways. Deploying the tool will require traffic safety, traffic engineering, and information technology staff to work together to complete the data mapping of existing state data into the software and validate the results. With a focused effort, it is estimated that the software's first phase could be deployed in six months to a year.

A phased implementation strategy for integrating *SafetyAnalyst* into standard practices at ADOT is recommended, along with a technology strategy to support the software implementation. The following implementation strategy is recommended for integrating the software into standard practices at ADOT:

- **Assign staff roles and responsibilities.** Major activities include creating a *SafetyAnalyst* Working Group (SA Working Group) and identifying the Data Administrator (ITG staff) and Application Administrator (ITG staff). The SA Working Group should be multidisciplinary and should consist of champions and staff with specific responsibility from both ITG and the TSS, as well as other business units such as the MPD and TEG. At a minimum, ITG and TSS staff should be involved on an ongoing basis in order for the model to be successfully developed and deployed. In order to achieve this ongoing commitment, ITG and TSS should consider and identify opportunities for ongoing staff availability and funding stream. In addition to annual *SafetyAnalyst* licensing fees ($25,000 in 2015), there may be expenses associated with such items as data needs, training and marketing, state or national travel for training, and user activities. ITG and TSS management may consider including *SafetyAnalyst* deployment and integration as a performance measure in annual performance responsibilities of staff on the SA Working Group.

- **Develop the model.** ADOT should address the identified data gaps by assigning actual values and assumed data values so the analytical tool can process the data. From a development and application perspective, it is recommended that ADOT start with the state network, and then expand the model in phases to include additional roadways. The model should be developed and deployed incrementally in the following order:
    - Phase 1: State roadway segments – *SafetyAnalyst* Modules 1 to 3.
    - Phase 2: State intersections – *SafetyAnalyst* Modules 1 to 3.
    - Phase 3: State ramp – *SafetyAnalyst* Modules 1 to 3.
    - Phase 4: All state roads – *SafetyAnalyst* Modules 1 to 4.
    - Phase 5: All public roads – *SafetyAnalyst* Modules 1 to 3 and finally Module 4.
- **Validate the model.** ADOT TSS staff should lead the efforts to conduct a validation for each phase and for the completed model to ensure that *SafetyAnalyst* is processing the input data records correctly. This can be done by comparing the preprocessed and postprocessed data for various descriptive elements, such as number of roadway segments, number of intersections, number of ramps, and number of crashes by segment. Ensuring that all values in the database are populated with a value will minimize the number of rejected data records.
- **Apply the model.** This activity includes developing a phasing plan for model applications within TSS, other units within ADOT, and, in the future, MPOs. The first three to five years of development and deployment should focus on the roadway segment network screening module. Until this module is well used within the DOT, the ADOT SA Working Group should focus on enhancing the data associated with this module, demonstrating the value of the model with ADOT-specific case studies, and providing training for staff. *SafetyAnalyst* also will be an excellent resource for the HSIP process. Over time, as TSS staff gain experience with the model, they should strive to identify additional users in the following order: other central office staff, district office staff, and MPOs. The research study recommends a phased approach for deploying the remaining modules.
- **Develop marketing and training programs.** Throughout the development and deployment of each phase of the model, ADOT TSS staff will be responsible for training ADOT staff on the appropriate use of the *SafetyAnalyst* tool. In some cases, the training will be limited to teaching users how to interpret and apply the outputs from *SafetyAnalyst*. In other cases, TSS will teach users how to use the software and how to interpret and apply the results. The training plan should be phased in according to the modules being applied and the business units potentially applying the model. As part of this program, ADOT should consider the need for training ADOT staff on how to teach *SafetyAnalyst* to others.
- **Develop deployment plans for each additional phase of the model.** Even as Phase 1 of the model has been developed and early application and deployment is underway, the SA Working Group should begin to develop a plan for enhancing the Phase 1 model or beginning development of the Phase 2 model. Enhancements will come in the form of addressing the data, application, database, or hardware gaps. Selecting the gap to address will, of course, be directly related to the extent to which the model is integrated into the HSIP process and the state

project development process. As more state and MPO users take advantage of the model, more needs will arise related to enhancing the model and training non-ADOT staff and consultants on the appropriate use of *SafetyAnalyst*.

The following technology strategy is recommended to support implementing the software and populating the *SafetyAnalyst* database for distribution and use.

- **Implement the enterprise deployment of *SafetyAnalyst*.** The ideal condition for *SafetyAnalyst* at ADOT is to use an enterprise environment for data storage and distribution. This distribution model will use Microsoft SQL Server for centralized storage and dissemination of calibrated *SafetyAnalyst* data. Compared to the stand-alone configuration, this option will reduce the risk of outdated data and eliminate multiple data copies across the network.
- **Populate the *SafetyAnalyst* database for distribution and use.** ADOT would need to perform the following activities to successfully implement an enterprise *SafetyAnalyst* deployment and populate the *SafetyAnalyst* database for distribution and use:
    - Develop conceptual design. ADOT should develop the conceptual design for the three software tools (Administration, Data Management, and Analytical) and two core databases (System Data and Calibrated Distribution Data) of *SafetyAnalyst*.
    - Identify software/hardware locations. ADOT ITG should identify and establish a permanent location for the Administration Tool, the Data Management Tool, a Derby data preparation database (preprocessing), and a SQL Server database for distribution.
    - Develop *SafetyAnalyst* data model and data import schema. ADOT should develop the *SafetyAnalyst* data model and data import schema for roadway, crash records, and traffic data.
    - Data maintenance/update (initial creation). ADOT should use the local Derby database for initial data creation procedures to minimize connectivity and application-related errors during the loading process. Once the data are error free, it should be loaded into SQL Server for distribution. Any agency overrides should be altered or created in the Administration Tool prior to creating and loading the import files. *SafetyAnalyst* uses tabular data to reference and analyze roads, crashes, traffic, and countermeasures. Therefore, all data must have a common and standard location reference for each data element. GIS and LRS are recommended for generating this commonality. For future maintenance/updates, the *SafetyAnalyst* data refresh cycle should coincide with the publication of ADOT MPD GIS data reports for the prior year, including the HPMS, Certified Public Mileage, State Highway System Log, and others.
    - Preparation of roadway, crash record, and segment traffic data. The pilot project found that a null or blank value always resulted in *SafetyAnalyst's* rejecting the data record. Although "unknown" values are acceptable for data loading, a record with an "unknown" value is likely to be rejected by *SafetyAnalyst* during postprocessing and will not be available for analysis. Therefore, any "unknown" values should be replaced with an educated guess or best judgment based upon ADOT standards. These judgments can be recorded and subsequently refined as resources become available.

- *SafetyAnalyst* Loading. Once all of the input data are prepared, the .txt files are ready to be loaded into *SafetyAnalyst*. The data manager can use the Data Management tool within *SafetyAnalyst* to load data and perform the necessary data processing.
- *SafetyAnalyst* Installer. The output of the Create Installer process is an executable file that is ready for distribution.

- **IT Enhancements.** The research project identified two specific IT-based enhancements that would bring added value to ADOT if implemented:

    - ETL scripts. The overall data preparation and conversion process is tedious, time-consuming, and prone to errors and/or inconsistencies in methodologies. Therefore, ADOT should invest in the automation of the data preparation steps to reduce this risk. Additionally, as *SafetyAnalyst* data are updated for each distribution, numerous data preparation cycles may be required before a clean import process (error free) can be completed. An automated data preparation script would greatly enhance ADOT's ability to quickly identify and correct errors and try importing data again. All of the processes used in the data preparation are tools that can be linked together to assist in the generation of the import files; therefore, the level of effort required to create an automated process is likely to be well worthwhile if it saves subsequent efforts to generate two or three cycles of import data.
    - GIS interface to import data. *SafetyAnalyst* uses tabular data to analyze specific locations and segments; therefore, the outputs and analysis results are tabular as well. The pilot process quickly identified the potential benefit of being able to see the data inputs and analysis results on a map when trying to identify what is happening at a particular location or why a certain result is occurring. This could easily be achieved by spatially enabling the import files with the LRS and providing this map to users. The import files have a route and measure associated that is referenced to the GIS; therefore, a map display would be relatively easy to provide.

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APPENDIX A. SITE VISIT AGENDA

Time	Topic
8:15	Gather, Introductions, Get Settled
8:30	The *SafetyAnalyst* Story at the DOT • Why *SafetyAnalyst* was selected • Implementation – when did it start, how long did it take to implement • How *SafetyAnalyst* is being used now • Pros/Cons • Demonstration
9:00	How the DOT is Using *SafetyAnalyst* (Detailed Discussion) • What steps in the Roadway Safety Management Process is the DOT using? • Are all *SafetyAnalyst* modules being used? • To what degree is *SafetyAnalyst* fully integrated into the project development process (project identification, prioritization, scoping, design, construction/system modification, safety performance evaluation)? • Has the DOT developed any new applications of *SafetyAnalyst*? What roadway types does the DOT use in *SafetyAnalyst*? All roadways, or was there a phased implementation? • Has the DOT evaluated or validated *SafetyAnalyst* results in any way? • What would the DOT have done differently in implementing *SafetyAnalyst*?
10:00	Break
10:15	Implementing SA – Data • Enterprise or stand-alone Implementation? • Is the DOT using the complete data schema or just a subset? • What was the level of effort required to populate the SA schema? What was the condition of the GIS/source data? • Any custom Data or Tool developments to assist with the handling or manipulation of SA data? Does the DOT have a GIS interface for SA or SA data?
10:45	Implementing SA – Data Schema Specifics/Details • Roadway Segment Configuration • Crash Location, Association and Relationship • Intersection Relationships and designation related to road segments and crashes • SA attribute code designations vs. source data code designations – Difficulties, Problems, Lessons?
11:15	Implementing SA – Data Integration/Data Warehouse • Did the DOT develop ETL scripts to automate the population of the SA schema? • Is the SA schema "integrated" with any enterprise resources (GIS, Data Warehouse, Crash Database)?
Noon	Lunch
1:00	Implementing SA – IT Needs • End-User workstation specifications • Database server specifications (if applicable) • Any network/server/workstation load problems or issues? • Any Custom Tools or Processes utilized? Any Suggested/Needed? • Is the DOT using a complex security/credential scheme or is SA open to all, limited to specific group, etc.? • Any issues using a JAVA database or Apache Derby? Or is the DOT using Oracle/SQL Server/other? • Has *SafetyAnalyst* been updated since initial implementation? What maintenance and update procedures have been implemented?

Time	Topic
2:00	Implementing SA – Staffing and organizational requirements • What institutional structure was used? Was the model implemented within the IT group or Safety Group? Is it a central office function or are regions using it? How many people are using *SafetyAnalyst*? • Training needs – Who was trained (technical staff, executive management)? How trained? How did the DOT institutionalize the application of *SafetyAnalyst*? • What were the costs associated with deploying *SafetyAnalyst* (e.g., staff time, licensing, material costs, etc.)? What type of funding was used?
2:30	Break
3:00	Lessons Learned (Arizona DOT to attend via phone) • What worked well? What didn't? What would the DOT have done differently? • Institutional lessons learned as they relate to ADOT's needs and data requirements.

APPENDIX B. OHIO DOT PRESENTATION MATERIALS

OHIO DEPARTMENT OF TRANSPORTATION

JOHN R. KASICH, GOVERNOR   JERRY WRAY, DIRECTOR

Safety Analyst Briefing Session

AASHTOWare Safety™ Analyst — AASHTO

Columbus, Ohio

February 28th and March 1st

Why SafetyAnalyst was selected

- **Improve location identification based on HSM Methodology**
- **Use a statistical approach for safety**
- **Versatility within the program**
- **Customizable**
  - Crash Data
  - Site Types
  - Performing multiple analysis runs based individual users needs
- **Replace legacy systems housed on Mainframe**

Safety Analyst Story at Ohio DOT   2

Implementation

- ODOT began working with the program in December 2007
- Worked with ITT and MRI to make enhancements to the beta version of Safety Analyst
- Developed the Priority Lists and Methodology for the 2011 HSIP Program
- First Published list was created in July 2011

How SafetyAnalyst is being used

- Priority Location Identification
- Countermeasure evaluation
- Some districts have used the diagnosis and countermeasure selection module

SafetyAnalyst Pros/Cons

Pros:

- Studying fewer locations with more crashes at higher severity rates
- Customization of screening
- Adds in implementing the highway safety manual across the department
- Strong Program Support with ITT and MRI

Cons:

- Data intensive
- Unfamiliarity with the tool
- HSM Methodology is difficult to explain to the public

SafetyAnalyst Demonstration

- Demonstration

Roadway Safety Management Process

- **What steps in the Roadway Safety Management Process is ODOT using?**
  - Network Screening
  - Diagnosis
  - Select Countermeasure
  - Safety Effectiveness Evaluation

SafetyAnalyst modules

- **Is ODOT using all SafetyAnalyst modules?**

- **Module 1 : Network Screening**
- **Module 2 : Diagnosis and Countermeasure Selection***
- **Module 4: Safety Effectiveness Evaluation**

***Some Districts have been using this to see if there are some different recommendations that they haven't considered.**

Safety Analyst Integration

- **To what degree is SafetyAnalyst fully integrated into the project development process (project identification, prioritization, scoping, design, construction/system modification, safety performance evaluation)?**
  - Project Identification – No
  - Prioritization – Yes
    - Yes since July of 2011
  - Scoping – No
  - Design – Yes
    - Starting in July 2013 we will use Safety Analyst as a preliminary requirement that identifies if a Design Exception will be required for safety
  - Construction/System Modification – No
  - Safety Performance Evaluation – Early Stages
    - We have began importing systematic projects into the tool
    - Working on adding all safety projects

New Applications of SafetyAnalyst

- **Has ODOT come up with any new applications of Safety Analyst?**
  - Used in the Long Range Plan to project crashes into the future based on roadway type and future AADT
- **What roadway types does ODOT use in SafetyAnalyst? All roadways, or was there a phased implementation?**
  - State System Route
  - Currently do not have Ramp segments loaded
    - We use an interchange site type
  - Working on including the local system

Evaluated or Validated SafetyAnalyst

- **Has ODOT evaluated or validated SafetyAnalyst results in any way?**
  - Verified the results against hand calculations for predicted number of crashes
  - Comparison against historical priority location methodology
  - Several comparisons between the results and emphasis areas

How Ohio DOT is Using SafetyAnalyst 11

Implementation Changes

- **What would ODOT have done differently in implementing SafetyAnalyst?**
  - We have found a few of our assumptions were incorrect.
    - Four approach intersection when it really was only 3 because of one-way streets
    - Made some assumptions about all way vs. two-way stop controlled.

How Ohio DOT is Using SafetyAnalyst 12

Enterprise Implementation

- **Enterprise or Stand-alone Implementation?**
  - Central Office Safety Staff uses a Derby installation
    - Use derby for testing and troubleshooting
    - Central office is aware of updates to SA and know to install a new derby client
    - It is much faster
    - Use the Derby database to run statewide priority lists
  - Enterprise Distribution
    - All District Safety staff and Central Office Staff not in safety have this installation

Implementing SA – Data 13

Safety Analyst Data Schema

- **Is ODOT using the complete SA data schema or just a subset?**
  - We enter all required attributes
  - Do not import intersection leg and ramp tables

Implementing SA – Data 14

Data Population

- **What was the level of effort required to populate the SA schema? What was the condition of the GIS/source data?**
  - Effort was focused on data translations and collection of additional attributes
  - Everything is linked by our linear referencing system

Custom Data and Tools Used

- **Any custom Data or Tool developments to assist with the handling or manipulation of SA data? Does ODOT have a GIS interface for SA or SA data?**
  - Spreadsheet evaluation tool for processed data
  - Worked to get the CSV reports customized so they are compatible with GIS mapping services

Roadway Segment Configuration

- **See Spreadsheet**

Implementing SA – Data Schema Specifics/Details 17

Linking Crashes and Road Inv

- **Crash Location, Association and Relationship**
  - If a crash is logged, a LRS point is assign to the crash.
  - Crashes are brought forward each year to the official road inventory when updated
  - Easily link crashes to road inventory

Implementing SA – Data Schema Specifics/Details 18

Intersection Crash Assignment

- **Intersection Relationships and designation related to road segments and crashes**
  - Intersections are currently includes all routes that intersect a state route
  - We use segment AADT and thru lanes as part of the intersection attribute assignment

Code Designations

- **SA attribute code designations vs. source data code designations – Difficulties, Problems, Lessons?**
  - Tool can manage either SA values or user specified
  - Db to Db SA can translate the values from source to SA designated

Populating SA Schema

- **Did ODOT develop ETL scripts to automate the population of the SA schema?**
  - Yes, currently on Mainframe
  - Being updated on Oracle

Populating SA Schema

- **Is the SA schema "integrated" with any enterprise resources (GIS, Data Warehouse, Crash Database)?**
  - Not at this point
  - Use CSV files exclusively
  - Import data will be available in Oracle

End-User workstation specs

- **End-User workstation specifications**
  - http://www.safetyanalyst.org/hardware-software-req.htm
  - Central Office Staff
    - Windows 7 – 64 bit OS; Intel i7 - Quad Core; 16.0GB RAM
  - District Safety Engineers
    - Windows 7 – 64 bit OS; Intel i7 - Quad Core; 4.0GB RAM

Database Server Specs

- **Database server specifications**
- **Oracle 11g**

Load Problems or Issues

- **Any network/server/workstation load problems or issues?**
  - Use Derby Database to load into Oracle tables directly.
  - Post processing in Oracle database is time consuming.

Custom Tools or Processes

- **Any Custom Tools or Processes utilized? Any Suggested/Needed?**
  - Excel analysis
  - GIS analysis
  - Db Visualizer
  - Maybe because we use CSV exclusively to import data

Security Scheme

- Is ODOT using a complex security/credential scheme or is SA open to all, limited to specific group, etc?

- Only write access to countermeasure tables
- Enterprise distribution
  - Open to all who have the client installed

Issues using different database types

- Any issues using a JAVA database or Apache Derby? Or is ODOT using Oracle/SQL Server/other?

- We use both Apache Derby and Oracle

Safety Analyst Update Cycle

- Has SafetyAnalyst been updated since initial implementation? What maintenance and update procedures have been implemented?
- Software is updated as the problem reports are addressed. There are nightly build and stable build releases
- The enterprise install is created twice a year
  - We use the latest Safety Analyst Stable build that is available
  - Triggers to update the enterprise install are annual road inventory updates and annual crash close out.

Implementation Team

- What institutional structure was used? Was the model implemented within the IT group or Safety Group? Is it a central office function or are regions using it? How many people are using SafetyAnalyst?
  - It was initiated by the Safety group but obtained IT support
  - It is maintained by central office and district offices use it for local screenings and evaluations
  - Mainly screenings and countermeasure evaluations
  - Have used it for diagnosis and countermeasure selection in some districts

Safety Analyst Training

- **Who was Trained?**
  - Central office and District Safety Engineers
- **How Trained?**
  - FHWA, MRI, ITT
  - Traveled to Columbus
  - Bi-Weekly Webinars for data and for application
- **How did ODOT institutionalize the application of SafetyAnalyst?**
  - Central Priority Lists
  - Support for District Engineers for site subtype and/or crash type analyses

Deployment Costs

- **What were the costs associated with deploying SafetyAnalyst (e.g., staff time, licensing, material costs, etc.)? What type of funding was used?**
- **Cost Associated with Deployment:**
  - Licensing amount changes annually.
    - Currently, $35,000
  - ODOT staff is used to create and maintain data systems and software testing
  - No separate material costs
- **IT funds license**

Lessons Learned

- What worked well? What didn't? What would ODOT have done differently?
- Institutional lessons learned as they relate to ADOT's needs and data requirements.

Lessons Learned 33

Questions?

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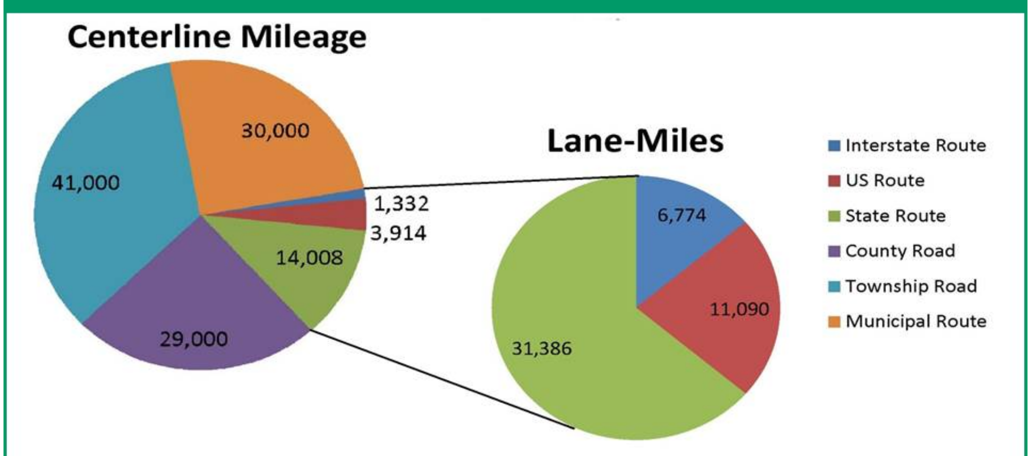
Safety Analyst Story at Ohio DOT 2

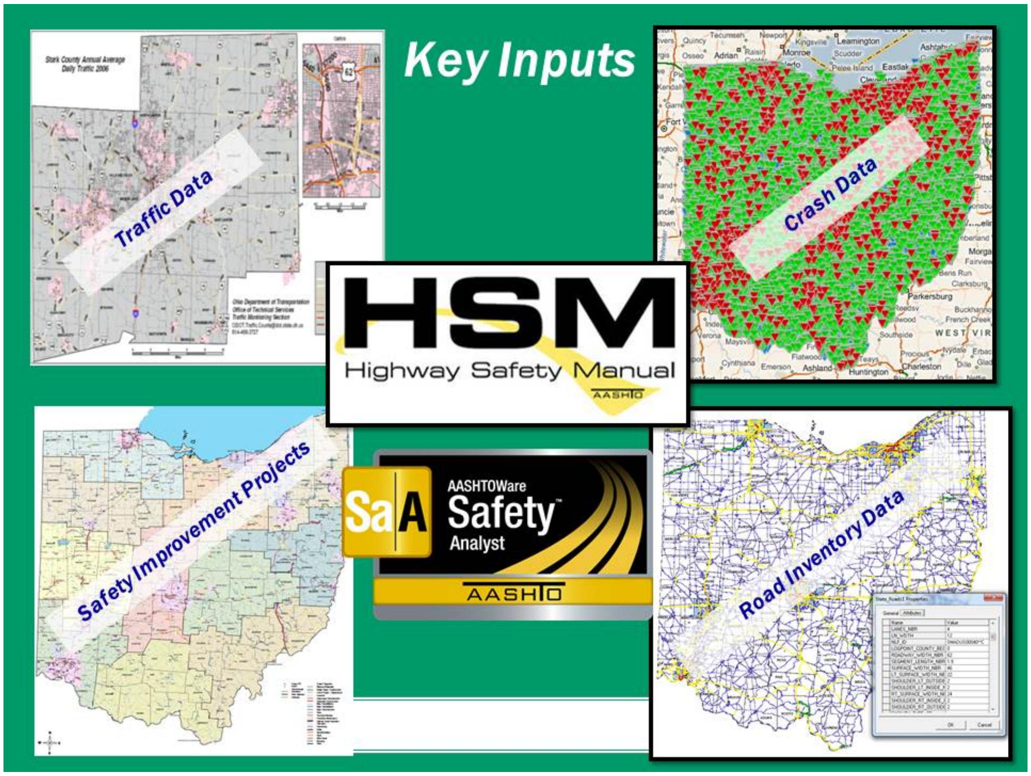
Ohio Statistics

- 2011: Safest year on record for Ohio's roadways
- 4th largest interstate system with 6,700 lane miles
- Single day's drive from 60% of U.S. population
- 7th largest state highway network
- Ohio is a "Home-Rule" State

Ohio's Roadway Mileage

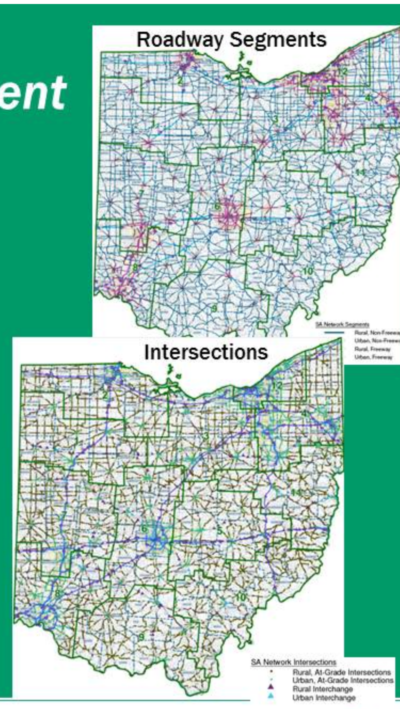


- Ohio's Total Centerline Mileage > 120,000 (all roads)
- Ohio's State System Centerline Mileage > 19,000 (IR, US, SR)
  - Ohio's State System Lane Miles > 49,000 (IR, US, SR)



SafetyAnalyst Development

- SafetyAnalyst Segment Data
  - Roadway Segments – 34,708
  - Segment Traffic – 183,717
- SafetyAnalyst Intersection Data
  - Intersections – 47,663
  - Major Road ADT – 255,971
  - Minor Road ADT – 61,218
- SafetyAnalyst Crash Data
  - 2002 – 2011
    - 1,600,000 Crashes



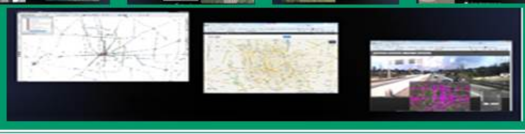
✧ IT has a process to map ADT data from historical years to current year with LRS audit trails

Highway Safety Asset Management

- Barrier Inventory – Proof of Concept

- Intersection Inventory

- Segment Inventory



SafetyAnalyst Required Elements

SafetyAnalyst Element	Requirements
Segment ID	Required during data import
Start Location	Required during data import
End Location	Required during data import
Segment Length	Required for post-processing
Roadway Class Level 1	Required for post-processing site subtype assignment
Median Type Level 1	Required for post-processing site subtype assignment
Access Control	Required for post-processing site subtype assignment
Two-Way vs. One-Way Operation	Required for post-processing site subtype assignment
Interchange Influence Area on Mainline Freeway	Required for post-processing site subtype assignment
Route Type	Required during data import
Route Name	Required during data import
Area Type	Required for post-processing site subtype assignment
Route Name	Required during data import
Direction	Required during data import
Number of Through Lanes	Required for post-processing site subtype assignment
Year	Required during data import
AADT	Required during data import
Intersection ID	Required during data import
Location	Required during data import
Intersection Type Level 1	Required for post-processing site subtype assignment
Traffic Control Type at Intersection	Required for post-processing site subtype assignment
Year	Required during data import
AADT	Required during data import
Year	
AADT	
Leg ID	
Type	gnment
Year	
AADT	
Year	Required during data import
Ramp ID	Required during data import
Start Location	Required during data import
Ramp Type	Required for post-processing site subtype assignment
Ramp Configuration	Required for post-processing site subtype assignment
Year	Required during data import
AADT	Required during data import
Accident ID	Required during data import
Location	Required during data import
Accident Date	Required during data import
Accident Severity Level 1	Required during data import
Number of Fatalities	Required during data import
Number of Non-Fatal Injuries	Required during data import
Relationship to Junction	Required during data import
Accident Type and Manner of Collision	Required during data import
Number of Vehicles Involved	Required during data import
Initial Direction of Travel	Required during data import
Vehicle Maneuver/Action	Required during data import

- Start with what you need

SafetyAnalyst Development

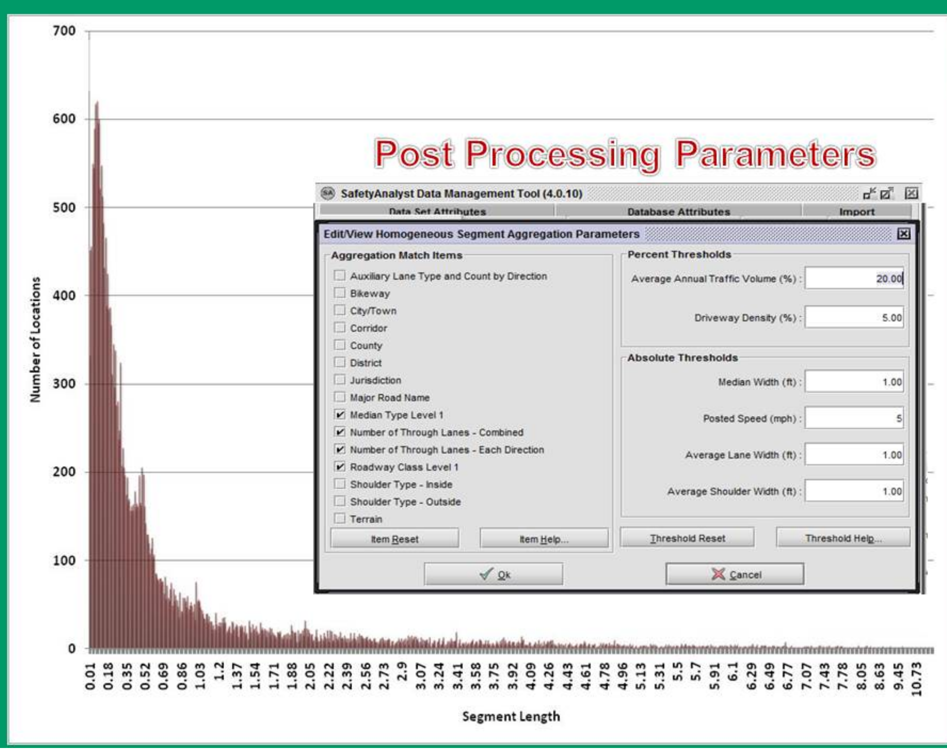
- Additional Crash Data Screening Elements (Customizable)
  - The Following Items Added to the Data to Perform Network Screening:
    - School Bus Related
    - Work Zone Related
    - Alcohol Related
    - Drug Related
    - Deer Related
    - Motorcycle Related
    - Speed Related
    - Commercial Motor Vehicle Related
    - Youth Related (16-25)
    - Senior Related (>64)
    - Pedestrian Related
    - Bicycle Related
    - Road Contour (Curve, Grade)
    - School Zone Related
    - No Restraint Used
    - Red Light Running

- Then add what you want

- Additional Site Subtype Development
  - Interchanges (Including Ramps)
  - Parking Sections
  - Interchange Influence Areas

9

SafetyAnalyst Software for Highway Safety Management AASHTO



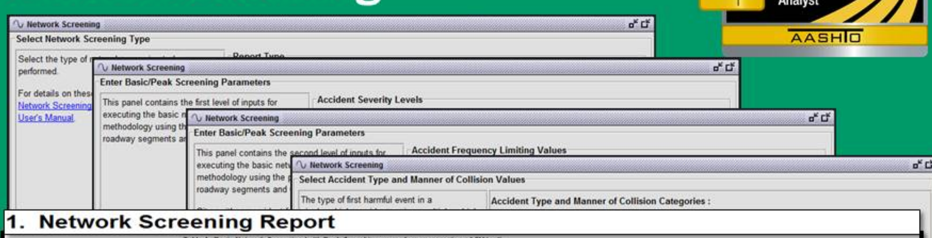
Site Subtype Analysis

- Listing of SA Site Subtypes
- Count of the Locations in each Site Subtype
- Sum of the Length of the Roadway Network if a Segment
- Count of the Crashes by Site Subtype
- Crashes per Intersection or Mile by Site Subtype

SA Site Subtype	Number of Locations	Sum of Length	Number of Crashes	Number of Crashes Per Intersection or Mile
Int/Rur; 3-leg all-way STOP	4		28	7
Int/Rur; 3-leg minor-rd STOP	4,586		13,202	3
Int/Rur; 3-leg signalized	54		880	16
Int/Rur; 4-leg all-way STOP	44		277	6
Int/Rur; 4-leg minor-rd STOP	19,785		42,213	2
Int/Rur; 4-leg signalized	577		12,209	21
Int/Urb; 3-leg all-way STOP	8		68	9
Int/Urb; 3-leg minor-rd STOP	6,507		60,622	9
Int/Urb; 3-leg signalized	1,004		32,263	32
Int/Urb; 4-leg all-way STOP	29		356	12
Int/Urb; 4-leg minor-rd STOP	8,972		65,253	7
Int/Urb; 4-leg signalized	4,629		241,599	52
Rural Interchange Signalized	40		1,836	46
Rural Interchange Stop Controlled	188		2,243	12
Seg/Rur; 2-lane	10,389	12,537	258,487	21
Seg/Rur; Fwy (4 ln)	358	697	38,521	55
Seg/Rur; Fwy (6+ ln)	57	169	16,651	98
Seg/Rur; Fwy in intchng area (4 ln)	407	182	13,574	75
Seg/Rur; Fwy in intchng area (6+ ln)	55	26	4,505	170
Seg/Rur; Multilane divided	638	668	23,776	36
Seg/Rur; Multilane undivided	421	137	7,708	56
Seg/Urb; 2-lane arterial	5,626	2,210	148,818	67
Seg/Urb; Fwy (4 ln)	610	413	34,593	84
Seg/Urb; Fwy (6 ln)	248	196	34,817	178
Seg/Urb; Fwy (8+ ln)	74	29	8,838	301
Seg/Urb; Fwy in intchng area (4 ln)	1,297	445	71,171	160
Seg/Urb; Fwy in intchng area (6 ln)	590	252	94,444	375
Seg/Urb; Fwy in intchng area (8+ ln)	186	89	43,549	492
Seg/Urb; Multilane divided	1,257	375	40,719	109
Seg/Urb; Multilane undivided	2,962	1,006	195,974	195
Seg/Urb; One-way arterial	366	68	8,827	130
Segment rural 1 lane	9	1	17	13
Segment rural Traffic circle	28	1	38	27
Urban 3 Leg Intersection; No Traffic Control	245		1,740	7
Urban 4 Leg Intersection; No Traffic Control	101		1,340	13
Urban Interchange No Traffic Control	1		69	69
Urban Interchange Signalized	413		68,114	165
Urban Interchange Stop Controlled	336		12,057	36
Urban Intersection, Greater Than 4 Legs	113		4,495	40
Urban Traffic Circle/Roundabout	27		612	23
Grand Total	**73,241**	**19,502**	**1,606,503**	

Network Screening

AASHTOWare Safety Analyst AASHTO



1. Network Screening Report

Table 1. Basic Network Screening (with Peak Searching on roadway segments and CV test)

Site Type	Site Subtype	County	Route	Site Start Location	Site End Location	Average Observed Accidents for Entire Site*	Location with Highest Potential for Safety Improvement: Average Observed Accidents*	Predicted Accident Frequency*	Excess Accident Frequency*	Variance**	Start Location	End Location	No. of Expected Fatalities	No. of Expected Injuries	Rank	Additional Windows of Interest
Segment	Seg/Urb; Fwy in intchng area (4 ln)	FRA	I00071R	17.12	17.13	1272.21	1272.21	74.20	1041.64	4547.53	17.12	17.13	-	-	1	
Segment	Seg/Urb; Fwy in intchng area (6 ln)	FRA	I00071R	17.86	18.09	338.33	647.65	73.22	561.87	3278.06	17.99	18.09	-	-	2	
Segment	Seg/Urb; Fwy (6 ln)	HAM	I00075R	8.97	9.0	682.74	682.74	32.06	541.48	537.75	8.97	9.0	-	-	3	
Segment	Seg/Urb; Fwy in intchng area (8+ ln)	FRA	I00270R	25.46	27.33	61.83	625.79	79.36	533.17	3336.45	25.76	25.86	-	-	4	
Segment	Seg/Urb; Fwy in intchng area (6 ln)	CUY	I00090R	16.25	16.28	632.42	632.42	41.87	523.94	1100.06	16.25	16.28	-	-	5	
Segment	Seg/Urb; 2-lane arterial	STA	SR00043R	18.26	18.27	635.04	635.04	8.86	522.59	381.44	18.26	18.27	-	-	6	
Segment	Seg/Urb; Fwy in intchng area (6 ln)	FRA	I00071R	19.54	19.61	589.75	589.75	70.93	503.02	3070.66	19.54	19.61	-	-	7	
Segment	Seg/Urb; Fwy in intchng area (4 ln)	FRA	I00670R	4.58	4.76	319.12	534.24	59.20	482.14	2906.89	4.66	4.76	-	-	8	
Segment	Seg/Urb; Fwy in intchng area (6 ln)	CUY	I00480R	21.52	21.54	554.11	554.11	56.30	444.56	1937.85	21.52	21.54	-	-	9	
Segment	Seg/Urb; Fwy in intchng area (4 ln)	HAM	SR00126R	19.61	19.64	552.47	552.47	20.59	436.71	384.33	19.61	19.64	-	-	10	
Segment	Seg/Urb; Fwy in intchng area (6 ln)	FRA	I00670R	2.24	3.31	110.75	486.19	30.26	425.54	604.43	3.14	3.24	-	-	11	2.34 - 2.44 2.84 - 2.94 3.04 - 3.14 3.21 - 3.31
Segment	Seg/Urb; Fwy in intchng area (6 ln)	LUC	I00075R	0.91	1.39	115.97	473.14	30.15	420.68	586.63	1.29	1.39	-	-	12	
Segment	Seg/Urb; Fwy in intchng area (4 ln)	FRA	I00270R	41.32	42.82	70.19	465.14	58.54	398.42	2819.74	42.72	42.82	-	-	13	
Segment	Seg/Urb; Fwy in intchng area (4 ln)	HAM	I00275R	31.15	31.22	473.48	473.48	64.43	398.17	3407.15	31.15	31.22	-	-	14	
Segment	Seg/Urb; Multilane undivided	LUC	SR00002R	13.78	13.79	644.51	644.51	13.36	390.35	169.22	13.78	13.79	-	-	15	
Segment	Seg/Urb; Fwy in intchng area (4 ln)	LUC	I00075R	4.82	4.89	412.41	412.41	50.46	350.10	2099.68	4.82	4.89	-	-	16	
Segment	Seg/Urb; Fwy in intchng area (6 ln)	CUY	I00090R	16.28	16.53	174.25	394.19	41.87	339.30	1087.34	16.43	16.53	-	-	17	
Segment	Seg/Urb; Multilane undivided	HAM	US00022R	11.39	11.41	432.29	432.29	25.21	338.17	566.63	11.39	11.41	-	-	18	
Segment	Seg/Urb; 2-lane arterial	HAM	SR00562R	0.0	0.22	223.29	368.83	31.51	335.37	4397.94	0.0	0.1	-	-	19	0.1 - 0.2

Countermeasure Evaluation Tool

2. CM(s): [Install LED flashing stop sign (a0)] Evaluation

Evaluation Type: Countermeasure: Percent Change in Accident Frequency
Countermeasures:
Install LED flashing stop sign (a0)

Site Subtype:
Int/Rur; 4-leg minor-rd STOP

Number of Sites in the Site List: 73196
Number of Sites Evaluated: 6
Average Years in BEFORE Period: 6.3
Average Years in AFTER Period: 2.7

Table 1. Overall Effectiveness

Severity Level	TOTAL
Evaluation	Percent Change in Accident Frequency
Accident Type and Manner of Collision	Collision with parked motor vehicle; Collision with railroad train; Collision with bicyclist; Collision with pedestrian; Collision with animal; Collision with fixed object; Collision with other object; Other single-vehicle collision; Overturn; Fire or explosion; Other single-vehicle non-collision; Rear-end; Head-on; Rear-to-rear; Angle; Sideswipe, same direction; Sideswipe, opposite direction; Other multiple-vehicle collision; Unknown; Multiple Vehicle Non-Collision; Backing; Left Turn
Effectiveness (Odds Ratio)	0.8882
Effectiveness (% Change)	**-11.182**
Direction of Change	**Decrease**
Variance (Theta)	0.017
Standard Error (Theta)	0.129
Standard Error (E)	12.926
Test Statistic	0.865
Significance	**Not significant at 90% confidence level**

Table 2. Evaluation with Empirical Bayes Approach, CM(s): [Install LED flashing stop sign (a0)], Total Accidents

Site	Countermeasure Location	Observed # of Accidents		Before Period # of Accidents		Expected # of Accidents w/o Treatment	Accident Reduction Effectiveness		B/C Ratio
		Before Period	After Period	Predicted w/SPF	Expected		Odds Ratio	Percent Change	
005564951005559018	Route US 40R, County MAD, Milepost 15.18	45.0	20.0	10.5583	40.7234	16.4172	1.2182	21.8235	-76.1592
001555917011484729	Route SR 729R, County CLI, Milepost 2.33	34.0	4.0	1.8047	19.7245	5.2038	0.7687	-23.1328	18.8810
001546924001555066	Route SR 73R, County CLI, Milepost 2.66	32.0	3.0	6.3393	27.1729	7.1084	0.4220	-57.7964	134.3962
001422605011457800	Route SR 32R, County CLE, Milepost 14.52	29.0	15.0	5.1715	23.8886	16.6563	0.9006	-9.9441	31.0898
000889198011269998	Route SR 32R, County BRO, Milepost 11.94	32.0	8.0	6.9520	27.6972	10.8431	0.7378	-26.2207	70.4784
Total									35.7372

Countermeasure Evaluation Tool

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Countermeasures:
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Total									35.7372

Crash Totals By Functional Class

Crash Locations by Functional Classification							
Functional Classification		State Crash Totals		Excess Crash Analysis		Expected Crash Analysis	
		Crash Totals		Number of Ranked Locations		Number of Ranked Locations	
1	Principal Arterial - Interstate (Rural)	14,468	3.8%	92	3.8%	3	0.1%
2	Principal Arterial - Other (Rural)	15,391	4.0%	73	3.0%	5	0.2%
6	Minor Arterial (Rural)	19,441	5.1%	83	3.4%	1	0.0%
7	Major Collector (Rural)	34,916	9.1%	36	1.5%	0	0.0%
8	Minor Collector (Rural)	2,223	0.6%		0.0%	0	0.0%
9	Local (Rural)	52	0.0%		0.0%	0	0.0%
11	Principal Arterial - Interstate (Urban)	72,604	19.0%	543	22.4%	915	37.0%
12	Prin. Art. - Other Frwy + Expwy (Urban)	17,130	4.5%	222	9.1%	167	6.8%
14	Principal Arterial - Other (Urban)	143,231	37.5%	959	39.5%	1,031	41.7%
16	Minor Arterial (Urban)	57,408	15.0%	391	16.1%	336	13.6%
17	Collector (Urban)	5,531	1.4%	30	1.2%	16	0.6%
19	Local (Urban)		0.0%		0.0%	0	0.0%
Grand Total		382,395		2,429		2,474	

Crash Totals By Route Type

2008 to 2010 Crash Locations by Route Type						
Trans Route Code	Statewide		Excess Crash Analysis		Expected Crash Analysis	
	Crash Totals		Crash Locations		Crash Locations	
IR	90732	22.3%	699	28.0%	1,334	53.4%
US	103264	25.4%	701	28.0%	455	18.2%
SR	212241	52.2%	1,100	44.0%	711	28.4%
Totals	406,237		2,500		2,500	

Analyzed both 0.3 and 0.5 Mile Windows

Excess Sliding Windows Overlapping a Peak Searching Location Study Summary						
Rank	0.3 Mile Windows			0.5 Mile Windows		
	Number of Unique Locations	Number of Intersection Locations	Study Length	Number of Unique Locations	Number of Intersection Locations	Study Length
1-500	443	2	125.25	413	2	185.44
501-2,500	1,754	489	362.13	1,703	489	561.49
Grand Total	2,197	491	487.38	2,116	491	746.93

Crash Total Comparison for Sliding Window Lengths					
Sliding Window Length	Total Crashes	Total Injury Crashes	Fatalities	Serious Injuries	Length
0.3 Mile	46,850	11,369	79	1,035	487.38
0.5 Mile	52,474	12,852	85	1,169	746.90
Difference	5,624	1,483	6	134	259.52
% Difference	12.00%	13.04%	7.59%	12.95%	53.25%

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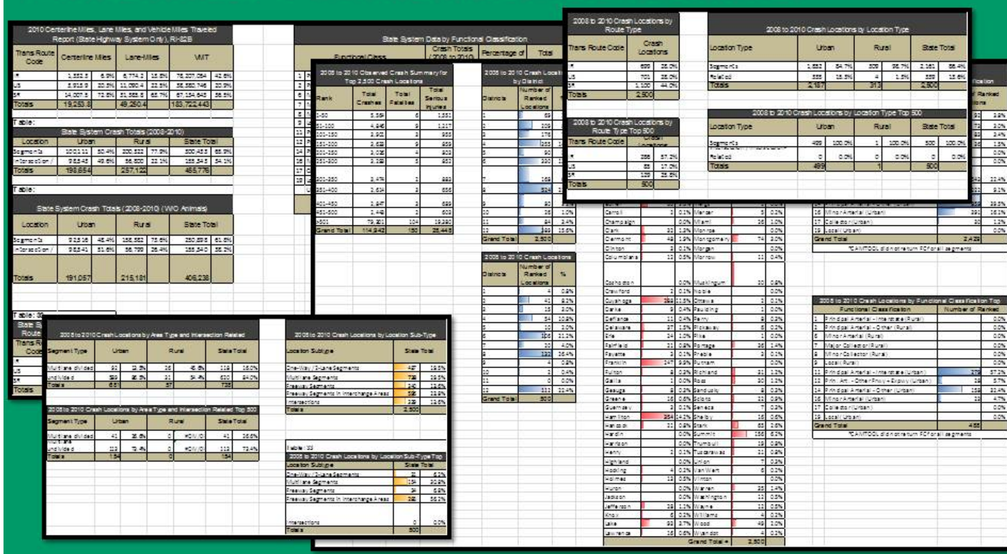
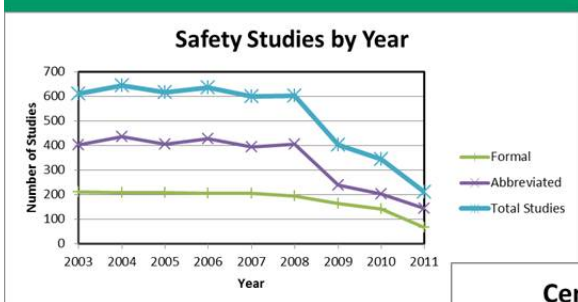
Evaluation Possibilities Are Endless

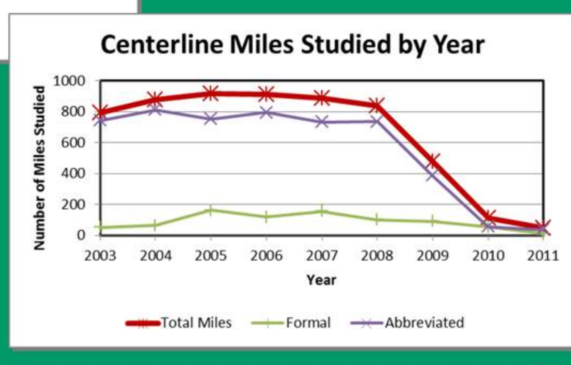


-Iterative improvements can be made over time

Safety Priority Locations - ODOT is using Safety Analyst



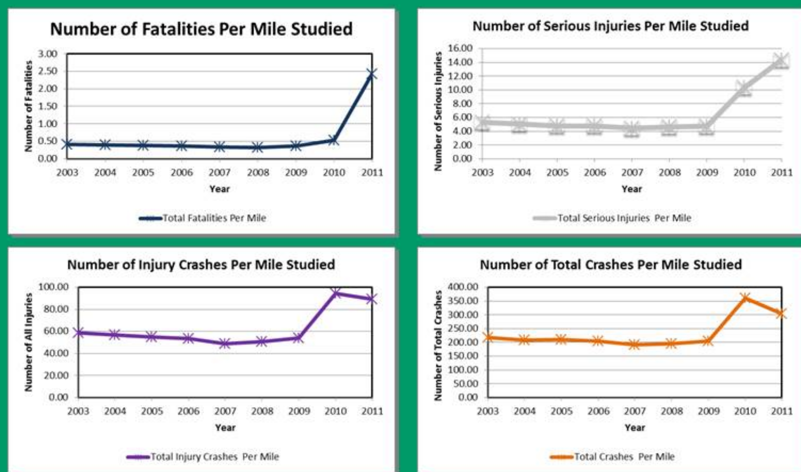
SA Implemented in 2010



- Reduced the number of manual safety studies performed from 600 to 300
- Greatly increased the identification of sites with highest potential for safety improvement

SA Safety Study Location Effectiveness

SA Implemented in 2010



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Key Elements to Consider / Challenges To Overcome

- **Support from management, IT, data providers, and users**
- **Inventories (intersections, segments, ramps, volumes, etc.)**
  - Managed by different groups
  - Different levels of accuracy and completeness
- **Buy-In from users that HSM/SA is better than old methodology**
  - Just as good won't cut it…why change if not better
- **Annual perpetuation of the road inventory, crash data, and volumes**
  - Historical years data must be conflated to the "current" system inventory
- **Data preparation for HSM / SA is an iterative process between IT and the business unit**
  - Road inventory anomalies (due to data errors)
  - Crash data questions (intersection related coded by officers or spatial buffer)
  - Remove animal crashes from analysis or not
  - Data managed by different offices
  - Help determine where data needs were lacking and prioritize their collection

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Key Elements to Consider / Challenges To Overcome

- **Support from management, IT, data providers, and users**
- **Buy-In from users that SA is better than old methodology**
  - Just as good won't cut it…why change if not better
- **Securing stable funding source for continued use**
  - SA must be integrated into core business to justify software
- **Inventories (intersections, segments, ramps, volumes, etc.)**
  - Managed by different groups
  - Different levels of accuracy and completeness
- **Translating existing state's crash data and inventory data into SA required codes**
- **Ensuring adequate computer hardware and software is utilized (adequate Ram & 64 Bit OS)**
- **Educating both users of the software as well as users of the outputs of the software**
  - Utilizes HSM state-of-the-art statistical methods

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Key Elements to Consider (Continued)

- **Annual perpetuation of the road inventory, crash data, and volumes**
  - Historical years data must be conflated to the "current" system inventory
- **Data preparation for SA is an iterative process between IT and the business unit**
  - Road inventory anomalies (due to data errors)
  - Crash data questions (intersection related coded by officers or spatial buffer)
  - Remove animal crashes from analysis or not
- **Determining the optimal solution for allowing district users access to the software – critical to consider for routine software updates**
  - Local Derby database install (single instance)
  - Network drive install with Oracle database on back-end (shared instance)
- **Substantial amount of implementation information on Wiki and other on-line documentation**

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SafetyAnalyst Benefits

- Improved our data collection processes and helped with needs assessment
- Help prioritize elements for asset management and road inventory
- Help identify site subtypes and flag locations where errors or data is missing and needs cleaned up
- Gives the districts the ability to run specialized and localized network screenings and site priority lists on an ad hoc basis
- Can view and extract all of the data used to identify and prioritize locations (crashes, volume, and inventory data)

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SafetyAnalyst Benefits (Continued)

- Vast array of analysis options and software capabilities
- Able to retire legacy analysis tools and antiquated technology (mainframe)
- Input implemented countermeasures (systematic/project) and evaluate the effects on highway safety – develop CMFs
- Further Ohio's efforts in the implementation of the HSM

I won't say the hardest step is the first one....but it will be the most important one! Good Luck.

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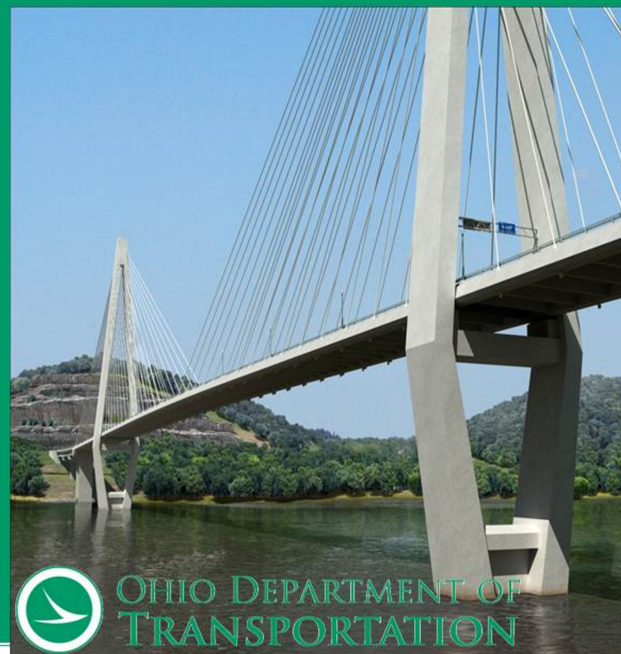
Summary Thoughts

- Integrate safety into all aspects of the department
- Ensure asset management collection efforts are prioritized and input is obtained from all affected stakeholders in the organization
- Implement improvements to data elements through an incremental and iterative process - with the goal of continuous improvement



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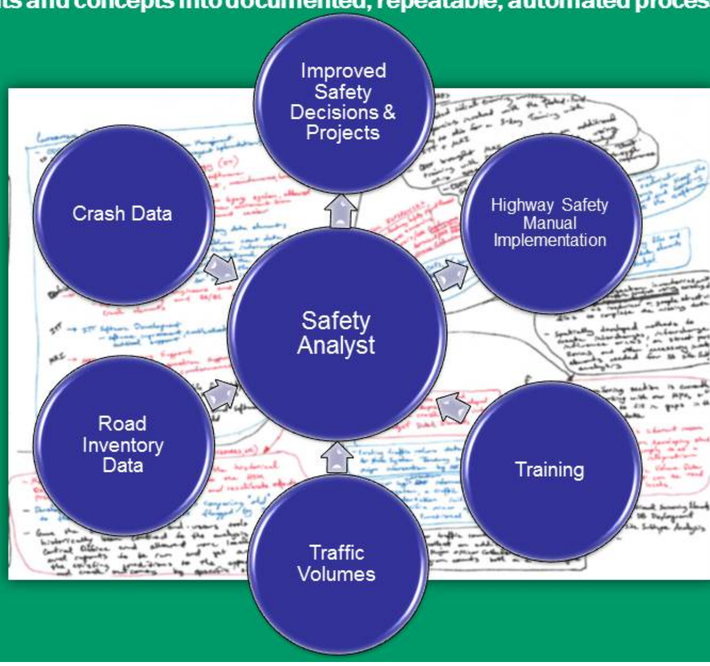
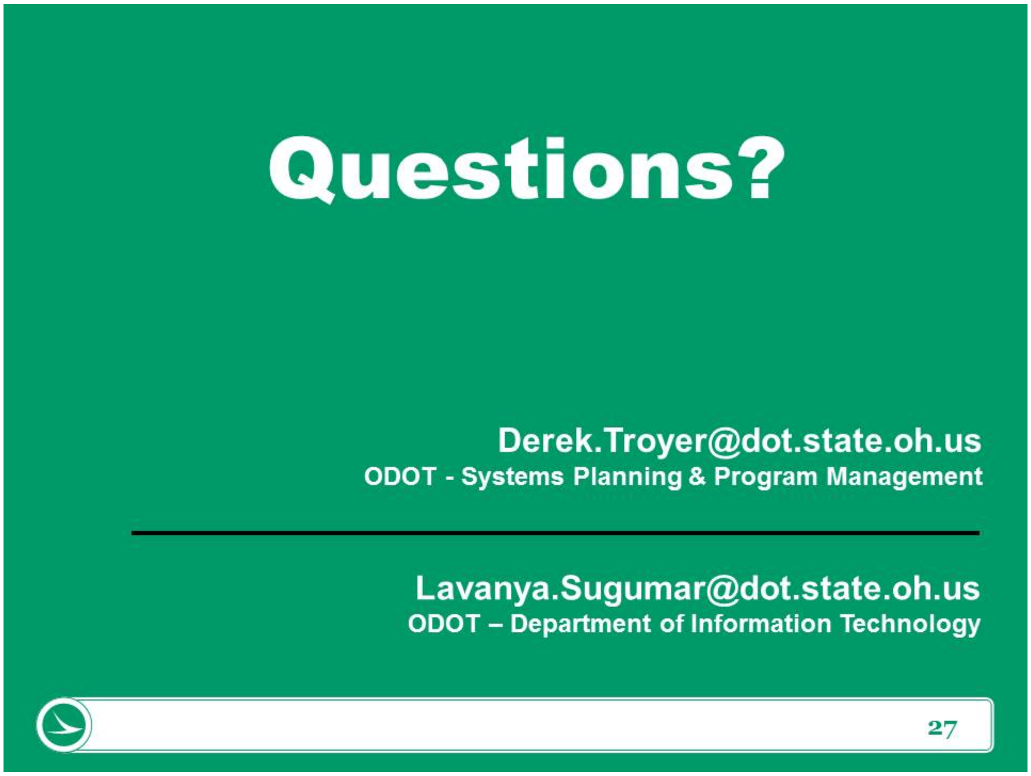
In the End – Organize the Chaos

- Turn thoughts and concepts into documented, repeatable, automated processes




Questions?
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APPENDIX C. ADOT STAFF INTERVIEWS

Interviewees

- Multimodal Planning Division (MPD) – James Meyer, Keith Killough
- Information Technology Group (ITG) – Haleh Farhadi, Traci Dennis, Jeff Wilkerson, Banchana Pandey
- Transportation Safety Section (TSS) – Mark Poppe, Kohinoor Kar, Pradeep Tiwari, Larry Talley

Interview Guide

<table>
<tr><th>Topic</th><th>Facilitator</th></tr>
<tr><td>GIS Data
• Roadway Geometry
o Segments/Routes
o Intersections
o Ramps
• Data Coverage (All Roads/State System)
• Data Attributes
o Traffic Volume
o Road Characteristics
o Turning/Movement
o Influence Areas
• Any Known Accuracy Issues?
• Any Known Data Gaps?
• Publication Schedule</td><td>David Ward</td></tr>
<tr><td>IT/AIDW
• Roadway Geometry
o Segments/Routes
o Intersections
o Ramps
• Data Coverage (All Roads/State System)
• Data Attributes
o Traffic Volume
o Road Characteristics
o Turning/Movement
o Influence Areas
• Any Known Accuracy Issues?
• Any Known Data Gaps?
• Crash/Safety Data Mart
• SafetyAnalyst Data/Application Support</td><td>David Ward</td></tr>
</table>

Topic	Facilitator

Traffic Safety
• Desired Application of *SafetyAnalyst*
  o All Modules?
  o "All Roads"?
  o Safety Programming or All Projects?
  o Overlap with HSM Implementation Goals
• Intended User of *SafetyAnalyst*
• Data Attributes
  o Traffic Volume
  o Road Characteristics
  o Turning/Movement
  o Influence Areas
• Any Known Accuracy Issues?
• Any Known Data Gaps?
• Crash/Safety Data Mart
	Beth Wemple