Performance Measures for Roadway Inventory Data

MIRE
MODEL INVENTORY OF ROADWAY ELEMENTS
Dictionary of Roadway Data Elements for Safety

FHWA Safety Program

U.S. Department of Transportation
Federal Highway Administration

Safe Roads for a Safer Future
Investment in roadway safety saves lives

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FOREWORD

The Federal Highway Administration's (FHWA's) Highway Safety Improvement Program (HSIP) is a data driven program that relies on crash, roadway, and traffic data for States to conduct effective analyses for problem identification and evaluation. The FHWA developed the Model Inventory of Roadway Elements (MIRE) to provide a recommended listing and data dictionary of roadway and traffic data elements critical to supporting highway safety management programs. MIRE is intended to help support the states' HSIPs and other safety programs.

The MIRE Management Information System (MIRE MIS) was a project to explore better means of collecting MIRE data elements, using and integrating the data and identifying optimal data file structures. The resulting products include reports on the findings from the MIRE MIS Lead Agency Program, a MIRE Guidebook on the collection of MIRE, a suggested MIRE data file structure report and a report on collection mechanisms and gap analysis that will assist the states in conducting a more effective safety program. The intent of the MIRE MIS project is the integration of MIRE into States' safety management processes.

The *Performance Measures for Roadway Inventory Data* report is one of the products of the MIRE MIS effort. This report builds upon NHTSA's *Model Performance Measures for State Traffic Records Systems* report and identifies issues to be considered and measures to assess the quality of the roadway and traffic data. This report will provide data managers and collectors with refined techniques for assessing the quality of the roadway and traffic data inventory data they collect and maintain.

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Notice

Quality Assurance Statement

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16. Abstract

Performance measures for data systems are tools for helping assess data quality and establishing goals for data improvement. This report concerns the development of performance measures for roadway inventory data. Prior work by the National Highway Traffic Safety Administration (NHTSA) defined performance measures for timeliness, accuracy, completeness, uniformity, integration, and accessibility for each of the six core traffic safety data systems – crash, vehicle, driver, roadway, citation/adjudication, and injury surveillance. This report builds on those measures, providing a detailed review of each of the measures proposed for roadway data and suggesting modifications of and possible additions to that original list. The measurement of data quality using performance measures is of little value without follow-up efforts to correct problems identified. This report also provides suggestions for data-related business practices that can lead to the successful use of performance measures and to improvements in roadway 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)		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
		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)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	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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ACRONYMS

AADT	Average Annual Daily Traffic
CDIP	Crash Data Improvement Program
DOT	Department of Transportation
EMS	Emergency Medical Services
FHWA	Federal Highway Administration
GHSA	Governors Highway Safety Association
GIS	Geographic Information System
HPMS	Highway Performance Monitoring System
HSIP	Highway Safety Improvement Program
HSIS	Highway Safety Information System
IHSDM	Interactive Highway Safety Design Model
MAP-21	Moving Ahead for Progress in the 21st Century Act
MIRE	Model Inventory of Roadway Elements
MIS	Management Information System
MMUCC	Model Minimum Uniform Crash Criteria
MPO	Metropolitan Planning Organization
NHS	National Highway System
NHTSA	National Highway Traffic Safety Administration
PRG	Preusser Research Group
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users
TRCC	Traffic Records Coordinating Committee
VIN	Vehicle Identification Number
WSDOT	Washington State Department of Transportation

EXECUTIVE SUMMARY

The last decade has seen a marked increase in the emphasis placed on data-driven decision-making in the management of safety programs for State and local agencies. While crash data have long been considered an essential component of safety analyses, the value of other datasets—including roadway inventory and traffic volume data—has gained greater appreciation in recent years. A number of state-of-the-art analytical tools and resources have emerged that rely not only on crash data but also on roadway inventory data. For this reason, safety data of various types are becoming increasingly important in safety management efforts across the U.S.

SIX PERFORMANCE ATTRIBUTES

- ***Timeliness***
- ***Accuracy***
- ***Completeness***
- ***Uniformity***
- ***Integration***
- ***Accessibility***

The Federal Highway Administration (FHWA) has recently focused more attention on improving roadway inventory data nationwide. In 2010, FHWA released the Model Inventory of Roadway Elements (MIRE) Version 1.0. MIRE is a recommended listing of roadway and traffic data elements critical to safety management, and includes proposed standardized coding for each element. A critical step toward acceptance and implementation of MIRE is the conversion of MIRE, which is now a listing of variables, into a Management Information System (MIS). The purpose of this report is to develop performance metrics to assess and assure MIRE data quality and MIS performance. Although the focus of this report is on the MIRE data elements, the measures developed can be applied to all types of roadway-related data.

Performance measures are tools that can help to measure data quality and be used by States to establish goals for data quality improvement. The *Model Performance Measures for State Traffic Records Systems*—referred to subsequently as "the NHTSA Report"—is a publication released by the National Highway Traffic Safety Administration (NHTSA) in February 2011. In it, NHTSA defined measures for six performance attributes that could apply to each of the six core traffic safety data systems.

This report builds upon the roadway data performance measures presented in the NHTSA Report, providing a detailed review of each and suggesting modifications of and possible additions to that original list. These suggestions include the following:

- Reword the current language, where appropriate, to more clearly describe the measure by clarifying potentially confusing wording; e.g., the word "segment" is used to describe data attributes for both *road segments* and *intersections*.

- Use the measures independently for State-system and local-system roads to provide more detailed feedback.
- Consider the adoption of additional measures; e.g., a new measure could be added to assess the internal consistency of variables across all inventory files.

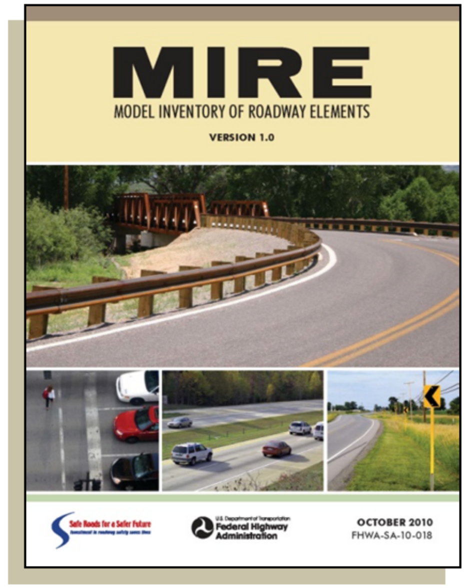
The measurement of data quality is of little value unless corrective action will be taken to address identified deficiencies within the data systems. These needs may be met through the following suggested data-related business practices:

- Establish or identify a roadway inventory leader.
- Establish an Inventory Coordinating Committee. (This could be part of the State's Traffic Records Coordinating Committee (TRCC) or a Data Improvement Committee within the State DOT).
- Establish roadway inventory performance measures.
- Calculate the measures regularly.
- Conduct follow-up analyses on the performance measures.
- Establish performance goals.
- Develop a system of internal quality-control checks.
- Increase the use of roadway inventory data.
- Develop high-level support for "getting it right."

Performance measures are tools that can be used to help increase the quality of roadway inventory data by examining the data performance quantitatively. In order to maximize the impact of performance measures on data quality, a number of questions should be addressed:

- Which measures are most likely to be useful to a given user agency?
- How should each measure be specifically defined and applied?
- What specific performance goals should correspond to each measure?
- Who will be responsible for measuring each of the performance attributes, and how often will this be done (e.g., monthly, annually, sporadically, etc.)?
- How will the implementation of and the staffing for a problem-correction procedure be funded?

CHAPTER 1: BACKGROUND AND INTRODUCTION



The Model Inventory of Roadway Elements (MIRE) is a set of roadway inventory variables that the Federal Highway Administration (FHWA) has identified as being critical to an effective contemporary highway safety management program. FHWA developed MIRE through a series of tasks, ranging from the initial collection of potential elements and element coding from a number of sources (e.g., Highway Performance Monitoring System [HPMS], SafetyAnalyst, etc.) to workshops and webinar reviews of the proposed elements by a national panel of potential users. The result of those efforts— *MIRE Version 1.0*—has been documented in a final report and is now available to user agencies *(1)*.

The National Highway Traffic Safety Administration (NHTSA) released the Model Minimum Uniform Crash Criteria (MMUCC) in 1998 to provide guidance on data collection practices at the scenes of motor vehicle crashes. Since then, MMUCC has undergone multiple revisions and has become the de-facto standard for crash data variables among various State and local jurisdictions. Many agencies across the United States have modified or even revamped their crash data systems based largely on the standardized data set outlined by MMUCC. MIRE is a companion to MMUCC, and it is envisioned that the impact of MIRE on roadway inventory datasets across the country may be similar to that of MMUCC on crash data.

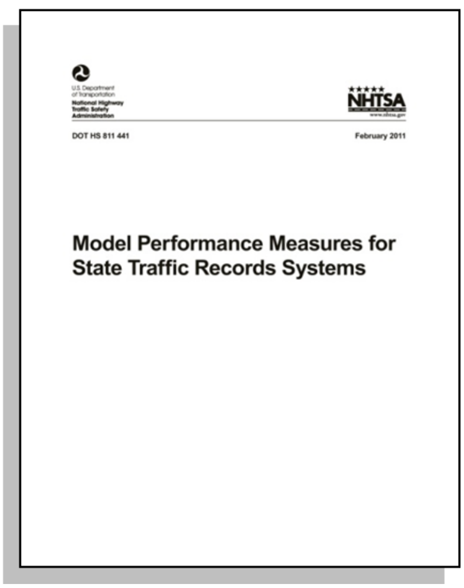
The potential benefits of MIRE on safety management programs nationwide are numerous, but its incorporation into the day-to-day safety practices of individual agencies will require significant effort. While virtually all State Departments of Transportation (DOTs) and many local agencies maintain roadway inventory databases, few of them are currently collecting the majority of the data variables within MIRE. Even if collected, agencies must often modify computer files, link new elements to other safety files, and incorporate the new elements into the computerized or manual systems and tools that are used in the safety decision-making process.

A critical step toward acceptance and implementation of MIRE is the conversion of MIRE (which is now a listing of variables) into a management information system (MIS). To assist States in developing and integrating the MIRE into an MIS structure that will provide greater utility in collecting, maintaining, and using MIRE data, FHWA has undertaken the MIRE MIS project. The proposed MIS design will include the exploration, development, and documentation of the following:

- Mechanisms for data collection.
- An efficient process for data handling and storage.
- Details of data file structure.
- Methods to assure (1) the integration of MIRE data with crash data and other data types, and (2) that access to these data can be accomplished through the MIRE MIS.
- The identification of performance measures to assess and assure MIRE data quality and MIS performance.

The purpose of this report is to address the last objective: to develop performance measures to assess and assure MIRE data quality and MIS performance.

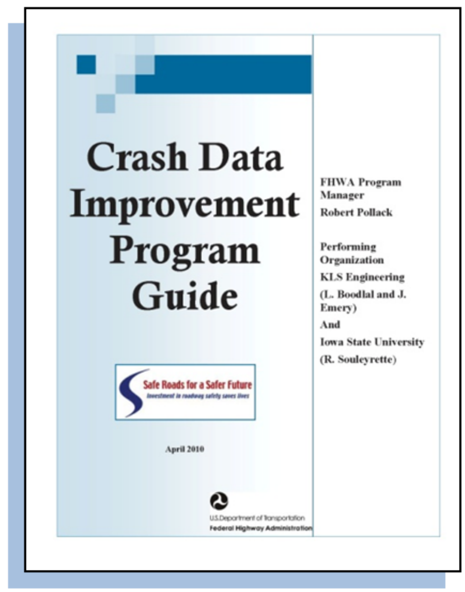
The development of performance measures for safety data became a high priority in 2005 with passage of the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU). This legislation authorized grants to States for traffic safety record system improvements under Sec. 408 of 23 United States Code (known as *Section 408* grants). The SAFETEA-LU language required States to set goals for their traffic safety record systems, to identify "performance-based measures by which progress toward those goals will be determined," and to subsequently demonstrate "measurable progress toward achieving the goals and objectives" outlined in the States' plans. NHTSA has since defined six core traffic safety data systems (crash, vehicle, driver, roadway, citation/ adjudication, and emergency medical services [EMS]/injury surveillance) that form the base of traffic safety records and six performance attributes (timeliness, accuracy, completeness, uniformity, integration, and accessibility) that can be considered when assessing the overall quality of each system. The new authorizing legislation, Moving Ahead for Progress in the 21st Century Act (MAP-21), continues traffic safety record safety system incentive improvement grants under Section 405.


NHTSA

DOT HS 811 441 February 2011

Model Performance Measures for State Traffic Records Systems

In 2008, NHTSA worked with State and Federal experts to establish a model minimum set of performance measures for behavioral highway safety programs *(2)*. Later that same year and with the assistance of the Governors Highway Safety Association (GHSA), NHTSA initiated a project to develop a more finalized minimum set of data quality performance measures for State traffic records systems. That group was to include at least one quality performance measure for each attribute for each of the six core traffic safety data systems. The development effort was coordinated by the Preusser Research Group (PRG) in collaboration with GHSA, and involved input from 25 State and 11 Federal data experts with extensive experience in the collection, processing, and utilization of data from each of the core systems. The results were documented in a July 2009 report entitled, "Model Performance Measures for State Traffic Record Systems White Paper: Request for Comment on Proposed Measures and Guidance" (hereinafter referred to as "the White Paper") *(3)*. The White Paper was widely distributed, and public comments were accepted by GHSA until early September 2009. The proposed performance measures were modified based on the feedback received, and an interim draft report was submitted to NHTSA in December 2009 *(4)*. NHTSA subsequently revised the minimum set of data quality performance measures to ensure its usefulness with regard to existing traffic records grant programs. Members of the original expert panel reconvened in 2010 to finalize the measures, and the final report (hereinafter referred to as "the NHTSA Report") was published in February 2011 *(5)*. All documents produced during the evolution of the performance measures—the PRG draft, the comments received from potential users, a pre-publication draft of the NHTSA report, and the NHTSA Report—were provided to this author and have been incorporated into later sections of this paper.


Crash Data Improvement Program Guide

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Performing Organization
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And
Iowa State University
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Safe Roads for a Safer Future

April 2010

U.S. Department of Transportation
Federal Highway Administration

In a separate but related effort, FHWA initiated the development of a Crash Data Improvement Program (CDIP) Guide in 2008 to provide States with a means to measure the quality of the information contained within their crash data systems. The final report was published in April 2010 *(6)*. While the CDIP Guide suggests crash data performance measures for the same six attributes that were identified in the NHTSA Report, it provides a much greater level of detail on each of the quality attributes, as well as real-world examples of measures currently being used by various State and local agencies. Much of the background discussion of performance measures found within this document is based on the CDIP Guide.

TERMINOLOGY

It is critical to employ concise language when discussing the performance of traffic records systems so that the users are not confused and the focal points are not misrepresented. Listed below are a few terms that could be potentially confusing, as well as an explanation of how those terms are used in this document.

- While the NHTSA Report and the CDIP Guide discuss the same areas and performance measures, each document uses different wording to do so. The CDIP Guide distinguishes performance metrics from performance measures: a *metric* is what is being measured (e.g., the number of days from when a crash occurred until when the crash database is updated is a measure of database timeliness); a *performance measure* is the change from the baseline or changes over preceding period (i.e., the improvement over a period of time). The NHTSA Report refers to the six areas of interest as *performance attributes* and refers to what is being measured as *performance measures*. It further notes that performance measures are different from performance goals, which refer to improvements in the measures over time and which are established by the user. To be consistent with the NHTSA Report, **this document will use *performance attributes* to refer to the six areas of interest (timeliness, accuracy, completeness, etc.).**
- The terms *milepost* and *milepoint* are used in linear-referencing methods to denote the specific location of a point along a roadway that is identified by a measured distance from a boundary—usually where the subject route crosses either a State or county line. **This document will use *milepost* and *milepoint* interchangeably.**
- A variety of technical resources are cited in this report, including the White Paper and the NHTSA Report, and, similarly, a number of authors are also mentioned. For clarity, **when a statement is an opinion or comment from the author of this document, it will be accompanied by the phrase, "this author."**

PROJECT TASK OBJECTIVES

The primary objective of this task is to develop a series of performance measures by which an agency can assess the *quality of data* in terms of timeliness, accuracy, uniformity, completeness, accessibility, and integration with the components of other traffic safety information management systems.

A secondary objective is to define *data governance* to help resolve any problems identified through the use of the performance measures, as the collection of the data-related performance measures without corrective follow-up efforts is of little value. The development of a listing of related good governance practices may help to improve the correction process. For example, consider a potential data accuracy measure: "the percentage of all road segment records with no errors in critical data elements." If an investigation concludes that the percentage of records having no errors is less than 100 percent, then governance practices with the potential to affect the data might include (1) the designation of a single data correction leader in the agency, and (2) the establishment of regularly scheduled intra-office team reviews of the noted issues. As errors are identified, the correction leader would need to determine what data collection and storage practices led to the errors and devise potential solutions to address these problems (which may include procuring new data collection technology).

PROJECT APPROACH

The initial step for this project was to gather existing information on performance measures by investigating (1) if and how States and local agencies currently use roadway data performance measures, and (2) what details on performance measures have already been illustrated by others in various research undertakings and reports, including the White Paper and NHTSA Report.

A substantial amount of information on how various agencies are presently employing data metrics was obtained from Appendix C of the White Paper, which provides a summary of the usage of metrics by 49 States and other jurisdictions in their data improvement plans and progress reports submitted for Section 408 data projects. This was based on a 2008 report from Traffic Safety Analysis Systems & Services, Inc. that summarized and catalogued the performance measures used by the States and other jurisdictions *(7)*. The author of the White Paper commented on the nature, extent, and appropriateness of the measures, noting a lack of structure and standard terminology and that the same or similar measure might appear under different categories in other States.

There were 107 total roadway inventory metrics: 19 for timeliness, 24 for accuracy, 32 for completeness, 8 for uniformity, 13 for integration, and 11 for accessibility in Appendix C. As mentioned by the White Paper author, many of these were in the wrong category. The number of States with at least one roadway data measure for a particular attribute differed from attribute to attribute. While 20 States had at least one measure for *completeness* of roadway data, only six States had at least one for *uniformity*. *Accessibility* seemed to be the most difficult performance measure to define, with some users trying to define it as "easily accessible" while others counted the number of users as a measure of accessibility. The roadway measure most frequently used across States involved *completeness* and was related to the percentage of road miles included in the database.

Complete details can be found in Appendix C of the White Paper, but some important findings are highlighted below:

- *Timeliness* – Thirteen States had at least one measure, but most were not true timeliness measures. Of the measures deemed appropriate, three dealt with the time lapse from the completion of construction to the updating of the data file, and three used a measure previously recommended by NHTSA concerning the amount of time from the end of the traffic count cycle to the latest annual average daily traffic (AADT) volumes being available in the data file.

- *Accuracy* – Sixteen States used at least one measure of accuracy, but many were related to completeness or integration. The most common occurrence was a measure of the percentage of crashes that could be located (which, as discussed below, is not a true measure of roadway accuracy). Three attempted to measure the geographical accuracy of the roadway file, and only one had a specific accuracy issue—examining the correctness of roadway width data.
- *Completeness* – Twenty States had at least one measure, dealing mostly with roadway file coverage either as a percentage of public roads, a percentage of State-system roads, or the number of county systems with all roads included.
- *Uniformity/Consistency* – Only six States had at least one uniformity measure. These varied widely, and only one dealt with uniformity directly—the "percent of databases using standard nomenclature for roads."
- *Integration* – Twelve States had at least one integration measure. Most appeared to be appropriate, dealing with the integration of county and metropolitan planning organization (MPO) files with the State file or map and the linkability of the roadway data with other traffic records files, including the crash file.
- *Accessibility* – Ten States had at least one accessibility measure, with approximately half related to the percentage of certain key customers (e.g., county engineers or MPOs) using the file or to some count of access by the public.

The second component of the information-gathering effort involved the review of various documents and reports that explored the current usage of roadway performance measures. Details were collected during a series of interviews as part of another task in the MIRE MIS project. A background statement concerning the definition and examples of roadway measures and performance goals was prepared and given to the interviewers, who posed two primary questions:

1. *Has your State developed formal inventory-data performance measure? (If so, please provide a list.)*

2. *Do you use any automated (i.e., computerized) quality-control checks of your inventory data? (If so, please provide examples.)*

Interviews were conducted with four State DOTs (Florida, Iowa, North Carolina, and Washington) and two local agencies (Winston-Salem, North Carolina and Orlando, Florida). Most of those interviewed employed some form of automated quality-control checks for a portion of their traffic records files. However, with the exception of the Washington State DOT (WSDOT), no positive responses were received concerning roadway performance measures. As part of a series of goals for all of its traffic records systems, WSDOT noted the following performance goal related to the completeness of its roadway inventory: *Increase the percent of statewide public road miles available for use in the Washington Transportation Framework database.*

In summary, while there are roadway inventory performance measures currently being used (or at least used during the preparation of Section 408 grant applications and progress reports), the specifics of their application vary greatly across the States. This inconsistency clearly supports the need for guidance such as that provided by the recent NHTSA Report and this document.

DISCUSSION OF MEASURES

The presentation of performance measures in Chapter 2 is organized by the six performance attributes identified above and provides the following details for each:

- The basic definition of the attribute, with material drawn primarily from the White Paper, the NHTSA report, and the CDIP Guide.
- The measures presented in the final NHTSA Report.
- A discussion of the performance measures proposed in this document.
- Possible modifications to proposed methods and additional performance measures for consideration. Example uses of the data performance measures in developing performance goals.

Chapter 3 presents a discussion of possible measure-related governance practices that may improve data quality.

GENERAL COMMENTS

There are a few points that merit discussion before delving into the individual data performance attributes:

- Since roadway inventory files contain an abundance of data elements—the first edition of MIRE contains 202 elements (plus eight additional suggested variables)—the effort required to establish measures for six different performance attributes for each data element would far surpass what is reasonable and effective. The NHTSA Report has addressed this issue in two ways:
    - First, the NHTSA Report states that "Use is voluntary: States should use the measures for those data system performance attributes they wish to monitor or improve. If the suggested measures are not deemed appropriate, States are free to modify them or develop their own,"*(5)*.

  - Second, the NHTSA Report suggests that certain roadway (and other database) performance measures only be measured for *critical* data elements, with the individual user agency making the determination of which elements are truly critical. (Further discussion of critical data elements in the roadway inventory file is provided under the timeliness attribute in Chapter 2.)

- While the roadway inventory file represents a single data system in the NHTSA Report, the roadway inventory dataset in most States actually comprises multiple files having multiple owners. In addition to a basic inventory file, there are also existing inventory files for highway-rail grade crossings and bridges in all States, as well as supplemental inventory files in many States related to focus areas such as asset management, pavement management, sign inventory, etc. These multiple sources of roadway inventory data within a single agency lead to increased complexity in both the choice of roadway performance measures and in the governance practices needed to achieve system-wide improvements. When choices of critical data elements and data improvement projects are made, consideration must also be given to each individual component of the roadway inventory system.

CHAPTER 2: PERFORMANCE MEASURES

In this report, the term *performance measure* is used to represent the specific feature or data quality characteristic that is being measured. The performance measures identified here are presented according to the six data performance attributes identified by NHTSA:

- Timeliness.
- Accuracy.
- Completeness.
- Uniformity.
- Integration.
- Accessibility.

Table 1 summarizes the metrics recommended in the NHTSA Report and additional measures suggested by this author. Both are discussed in detail below. The NHTSA Report, the White Paper, and the CDIP Guide provide general definitions of the six performance attributes. This information is captured under "Definition" in each discussion of the roadway data performance attribute. The NHTSA attribute naming convention (e.g., R-T-1) includes reference to the core data system (i.e., R = roadway), the attribute (i.e., T = timeliness) and the metric number (i.e., 1 = first metric), respectively.

The presentation of performance measures in Chapter 2 is organized by the six performance attributes identified above and provides the following details for each:

- The basic definition of the attribute, with material drawn primarily from the White Paper, the NHTSA report, and the CDIP Guide.
- The measures presented in the final NHTSA Report.
- The measures proposed in this document.
- Possible modifications to proposed methods and additional performance measures for consideration.
- Example uses of the data metrics in developing performance goals.

Table 1. Summary of NHTSA-recommended performance measures and author-suggested additional considerations.

NHTSA Data Performance Attributes	NHTSA Recommended Performance Measures	Suggested Revisions/Actions/ Additions regarding NHTSA Performance Measures
Timeliness	**R-T-1:** The median or mean number of days from (a) the date a periodic collection of a critical roadway data element is complete (e.g., Average Annual Daily Traffic) to (b) the date the updated critical roadway data element is entered into the database. **R-T-2:** The median or mean number of days from (a) roadway project completion to (b) the date the updated critical data elements are entered into the roadway inventory file.	**R-T-1:** Evaluate the utility of this metric to the State. **R-T-2:** No explicit suggested action.
Accuracy	**R-A-1:** The percentage of all road segment records with no errors in critical data elements. (The State selects one or more roadway data elements it considers critical and assesses the accuracy of that element or elements in all of the roadway records within a period defined by the State.)	**R-A-1:** Define the term "segment" in a broad sense to include records related to intersections, interchanges, and related inventories. <u>Additional Metric</u> **R-A-2:** Percentage of critical roadway inventory elements whose attribute values are within reasonable ranges and/or are consistent with related variables.
Completeness	**R-C-1:** The percentage of road segment records with no missing critical data elements. **R-C-2:** The percentage of public road miles or jurisdictions identified on the State's base-map or roadway inventory file. **R-C-3:** The percentage of unknowns or blanks in critical data elements for which unknown is not an acceptable value. **R-C-4:** The percentage of total roadway segments that include location coordinates, using measurement frames such as a GIS basemap.	**R-C-1:** No explicit suggested action. **R-C-2:** No explicit suggested action. **R-C-3:** No explicit suggested action. **R-C-4:** Road segments should also be considered as including intersections and interchanges/ramps. <u>Additional Metrics:</u> **R-C-5:** The percentage of critical elements actually collected in the roadway file layout. **R-C-6:** The percentage of total public road mileage that is included in the State's spatial data system.

Table 1. Summary of NHTSA-recommended performance measures and author-suggested additional considerations (cont.).

NHTSA Data Performance Attributes	NHTSA Recommended Performance Measures	Suggested Revisions/Actions/ Additions regarding NHTSA Performance Measures
Uniformity	**R-U-1:** The number of Model Inventory of Roadway Elements (MIRE)-compliant data elements entered into a database or obtained via linkage to other databases.	**R-U-1:** Consider changing "number" to "percentage." Additional Metric **R-U-2:** Percentage of critical roadway elements in all inventory files whose names, definitions, and coding are consistent across the target roadway system.
Integration	**R-I-1:** The percentage of appropriate records in a specific file in the roadway database that are linked to another system or file. (Example – bridge inventory records linkable to basic inventory file)	**R-I-1:** No explicit suggested action.
Accessibility	**R-X-1:** To measure accessibility of a specific file in the roadway database: Identify the principal users of the file. Query the principal users to assess (a) their ability to obtain the data or other services requested and (b) their satisfaction with the timeliness of the response to their request. Document the method of data collection and the principal users' responses	**R-X-1:** No explicit action suggested action. Additional Metric **R-X-2:** Number of users receiving information from the inventory file. **R-X-3:** Percentage of requests received for information or data from the State roadway inventory file that were filled within the State's defined timeline.

TIMELINESS

Definition

Timeliness usually measures *the duration of time between the event generating the data (e.g., a crash, a vehicle registration, etc.) and when those data are placed on file and available for use*. For data that should be provided to another system, timeliness can also measure the amount of time between the occurrences of events and when the data are submitted to the other system; e.g., consider citations sent to the court administrators, and the subsequent court actions that are sent to the driver history file.

For roadway data systems, timeliness typically refers to the duration of time between the opening of a new or modified roadway section and the placement of the associated data in the roadway inventory file. (Such a modification could include the installation of safety-related items such as signs, pavement markings, crash cushions, etc.) Timeliness could also refer to the time period between the systematic collection or updating of data and their placement within the database. A key example of this is the development of AADT estimates for each section of highway on an annual basis.

Differences between Roadway and Crash Data

There are fundamental differences between roadway data and crash data that must be considered when establishing measures for timeliness and other performance attributes. For instance, consider the date on which an event occurred—a critical factor in the assessment of the timeliness of an agency's data. If the event in question is a crash, then this information is typically entered into the crash database automatically since date is a specific field on the crash report. However, if the event of interest is a construction activity (e.g., the modification of an existing roadway), then a corresponding date may not be as readily available and, therefore, may not be regularly denoted within the roadway inventory database. Although an agency sometimes has a database that describes construction activities and maintenance reports that describe some safety-related treatments, capturing the actual date of a roadway improvement is generally much more arduous than capturing the date of a crash.

A key first step for the user agency is to decide what reference date is appropriate with regard to the roadway modification or the construction of a new facility. Ideally, the reference dates would be defined by a construction start date and the end the date on which normal traffic flow resumed (though this is not always possible). Next, a procedure should be established to record or extract this date for each project or action that will ultimately affect the roadway inventory. Timeliness would be defined, then, as the duration of time between the reference start date and the date on which the new data are entered into the inventory database.

This author notes several primary issues concerning the definition of timeliness as based on the amount of time between the event date and the date on which the database is updated to reflect that event.

- *The value and importance of timely updates to the roadway inventory database are often overlooked.* While it may be widely acknowledged that recent and up-to-date crash data may be required for state-of-the-art safety analyses, the critical role of roadway inventory data may not be as apparent. Because contemporary safety analyses rely on crash records being linked to roadway inventory data (and possibly other data), the timely and periodic update of the inventory file is crucial to an effective analysis of the most recent crashes. For example, if an agency's identification of high-crash locations incorporates the use of inventory data, then the appropriate data must be available by the time such analyses are conducted.
- *The location coding in the roadway inventory file should be in sync with that in the crash file.* The location attributes in an agency's data systems are often coded according to a linear-referencing system. This method typically defines the specific location of a point along a roadway by incorporating a measured distance from a known boundary or landmark (e.g., where the subject route crosses a county line or bridge). Because this method is tied directly to the centerline of the subject roadway, any physical alteration to that centerline has the potential to render the linear-referencing system inaccurate downstream of the alteration. Locations in the crash files are often determined by an investigator-measured distance from the crash scene to some known reference point. Since the milepost of the reference point is known, the crash milepost can be calculated. However, if a reconstruction project lengthens or shortens an existing roadway segment (e.g., a curve is lengthened downstream from an intersection that is used as a reference point), the after-treatment milepost for a given point along the roadway will differ from the before-treatment milepost for that same point. Thus, in trying to identify high-crash locations, crashes before and after the reconstruction having the same mileposts will not have occurred at the same roadway location. Such potential changes in mileposts can be addressed as they occur (e.g., by providing updated information on the new roadway to those responsible for determining crash mileposts) or at a specified later date (e.g., at the end of the year) if the date of the crash, the date of the improvement, and the amount of change in the after-modification mileposts is documented. It will be necessary for the user agency to establish a process that keeps the crash and inventory mileposts in sync. The critical date for documenting the inventory changes will likely be dictated by this process to insure compatibility between the location coding of each data system.
- *A critical timeframe for the updating of the inventory database may be dictated by practices beyond the realm of safety.* A roadway inventory dataset may be used for a variety of

purposes other than safety, and such applications may require that the system be updated by a particular date. As an example, the Ohio DOT uses the total route mileage information from its inventory to determine the amount of roadway taxes returned to localities, and this must be done by a certain date each year. Thus, the timeliness target associated with the inventory updates may be driven by uses other than safety.

NHTSA Report Measures

Listed below are the two roadway timeliness measures that were proposed in the NHTSA Report. Note that the NHTSA naming convention for measures (e.g., R-T-1) includes reference to the core data system (R = roadway), attribute (T = timeliness), and assigned performance measure number (1 = first measure), respectively.

- *R-T-1:* The median or mean number of days from (a) the date a periodic collection of a critical roadway data element is complete (e.g., AADT) to (b) the date the updated critical roadway data element is entered into the database.
- *R-T-2:* The median or mean number of days from (a) roadway project completion to (b) the date the updated critical data elements are entered into the roadway inventory file.

Each performance measure focuses on a separate type of event. The first (R-T-1) relates to data generated on a periodic basis through an ongoing data update procedure. The most obvious example of this is the estimation of traffic flow (i.e., AADT) for every section of roadway in a State. There could also be other full or partial system inventories conducted regularly by the roadway agency (e.g., asset management system updates requiring an inventory of roadside hardware, pavement markings, or sign conditions). The second measure (R-T-2) relates to modifications to the inventory file that arise from changes to the roadway attributes due to new roadway segments being opened or roadway improvements or modifications being completed along existing segments. Improvement projects cover a variety of activities, ranging from major reconstruction to something as straightforward as the installation of a warning sign. These changes occur sporadically throughout a given year.

Performance measure R-T-2 appears rational and needed, as it considers the duration of time between the completion of a construction project and the corresponding update to the database. It is associated with system changes that are critical to safety analyses, happen often, and are difficult enough to record and computerize to justify a measure. On the other hand, the usefulness of R-T-1 is slightly more questionable because it appears to be related to data collections that are ongoing and may happen less than annually. Clearly, some non-improvement-related data are critical to safety decision-making and should be incorporated into the inventory file as quickly as possible. Some of these data, such as AADT estimates, are required by the HPMS. It would appear that there are few cases where the data are not already being collected on a regular basis and entered into the inventory file in a timely fashion. While there is a need to record all newly-collected data in the roadway system in a timely manner, the question remains of whether a "standing" measure that is not used very often is needed to assess the quality of the data. If a roadway agency regularly collects non-improvement inventory data and there is no existing requirement (such as HPMS reporting) as to a timely incorporation of the data, then this measure would be useful.

Under proposed performance measure R-T-2, a State or other user agency would first need to define the terms *roadway project* and *completion*. From the safety analysis perspective, this author suggests that completion is best defined as *the date a roadway or roadway segment was opened to traffic.* Roadway projects, meanwhile, should include both those explicitly designated as safety projects (e.g., treatments at high-crash locations) and those that change one or more variables related to safety. For example, non-safety projects that address capacity may add lanes, modify lane and shoulder widths, add or modify medians, change speed limits, change curvature, upgrade intersection traffic control, etc. These changes are known to be safety-related, and thus data from such projects should be monitored. In many State roadway files, this type of data change is already being monitored and entered for State-maintained roads. The biggest question for States will be how best to expand the roadway dataset to also include non-State-maintained roadways. Comments on the original White Paper included suggestions that it may be necessary to have separate performance measures for State-system roads and non-system roads. This would appear to be a helpful proposition, since the definition of both projects and critical elements might differ between the two systems (especially if the safety analyses corresponding to each system differ).

Both of the proposed timeliness measures (as well as those related to accuracy and completeness that are discussed later) refer to *critical* inventory data elements. The NHTSA Report provides some guidance on the choice of these critical elements. It first notes that each State can define its own set of critical elements unless the measure includes a specific reference to elements in a national standard (e.g. HPMS). The discussion of timeliness, the NHTSA Report suggests that the short list of critical elements should be a subset of MIRE and could be some or all of the elements required for HPMS sites. (This would appear to mean the longer list of HPMS variables collected on sample sites [known as the *Full Extent* data] rather than the much shorter list of attributes collected on every segment or roadway.) MAP-21 specifies that a subset of MIRE be established and these elements be collected for all public roads. As noted above, the MIRE system currently defines 202 elements and eight additional files of suggested inventory elements. MIRE provides information on whether a variable is *critical* or *value-added*, but, even here, most of the variables are considered to be critical. While certainly possible and even desirable, analyzing this many variables each year would require a major effort; thus the importance of user-chosen critical elements. Interestingly, there is a crash-related uniformity measure in the NHTSA Report related to the number of MMUCC-compliant elements in the crash system. (It is noted that when all sub-elements in MMUCC are counted, the total number is similar to the number of MIRE variables.) This difference in the use of the two models likely reflects the age of both, with MMUCC being older and more entrenched among practitioners, so much so that it has become a (non-mandatory) national guideline for crash datasets.

The MIRE critical variables can be considered as a starting point for a user agency looking to define its own critical elements. MIRE also provides information concerning which variables are needed in the use of the Highway Safety Manual tools, the Interactive Highway Safety Design Model (IHSDM), and SafetyAnalyst. For States adopting the use of such tools, this information should also be helpful in the identification of critical variables. Table 2 lists the critical data elements that were suggested in the NHTSA Report.

Table 2. Critical data elements suggested in the NHTSA Report.

Critical Roadway Inventory Data Elements	
· Roadway Owner	· Intersections
· Route	· Divided/Undivided
· Surface/Pavement	· Horizontal Alignment Restriction
· Median	· Average Annual Daily Traffic
· Turning Lanes	· National Highway System
· Traffic Lanes	· Vertical Alignment
· Functional Classification	· Pavement Serviceability Index
· Shoulder	· Linear Reference System
· Access Control	· Mileage
· County	· International Roughness Index

On August 1, 2011, the FHWA Office of Safety issued a Guidance Memorandum that introduced a subset of MIRE elements referred to as the "Fundamental Data Elements" (FDEs). This list of 38 roadway and traffic data variables were deemed beneficial for use in the development and implementation of a State's safety programs *(8)*. As shown in Table 3, the suggested list of data elements was broken down into three primary categories: roadway segments, intersections, and interchanges/ramps. The memo provided the rationale for the list, along with guidance on collection priorities and possible sources of assistance.

Table 3. Fundamental Data Elements identified by FHWA.

Roadway Segment	Intersection	Ramp/Interchange
Segment ID*	Intersection ID	Ramp ID*
Route Name*	Location	Date Opened to Traffic
Alternate Route Name*	Intersection Type	Start Location
Route Type*	Date Opened to Traffic	Ramp Type
Area Type*	Traffic Control Type	Ramp/Interchange Configuration
Date Opened to Traffic	Major Road AADT	Ramp Length
Start Location*	Major Road AADT Year	Ramp AADT*
End Location*	Minor Road AADT	Ramp AADT Year
Segment Length*	Minor Road AADT Year	
Segment Direction	Intersection Leg ID	
Roadway Class*	Leg Type	
Median Type	Leg Segment ID	
Access Control*		
Two-Way vs. One-Way Operation*		
Number of Through Lanes*		
Interchange Influence Area on Mainline Freeway		
AADT*		
AADT Year*		

*HPMS Full Extent elements are required on all Federal-aid highways and ramps located within grade-separated interchanges, i.e., National Highway System (NHS) and all functional systems excluding rural minor collectors and locals.

MAP-21 required FHWA to identify a subset of MIRE elements that are useful for the inventory of roadway safety. The FHWA revised the FDEs and issued guidance. Changes between the original guidance memo and the revised FDEs can be found at the following link: http://www.fhwa.dot.gov/map21/qandas/qassds.cfm.

Suggested Modifications and Additions

The NHTSA Report proposed two measures for timeliness, R-T-1 and R-T-2. While no revisions to R-T-2 are suggested here, it is recommended that the real value of R-T-1 be evaluated. As discussed previously, R-T-1 pertains to data that are collected on an ongoing and regular basis, with AADT volumes being perhaps the most obvious example. Since the annual collection of AADT volumes and their timely delivery are required by HPMS, a "standing" measure in this instance may be duplicative and may not be useful to the State.

Example Use in a Performance Goal

Recall that R-T-2 has been defined as *the median or mean number of days from (a) roadway project completion to (b) the date the updated critical data elements are entered into the roadway inventory file.*

Assume that a State wishes to incorporate R-T-2 into a performance goal. Data are entered into the inventory database at the DOT Central Office when an as-built plan is received. Assume further that no date-of-entry is recorded in the inventory file for each variable. Based on this scenario, the following steps appear to be necessary:

1. <u>Determine which safety-related roadway projects are target projects.</u> The State must decide to which projects it would like to apply the measure. These could include Highway Safety Improvement Program (HSIP) projects or any that are related to changes in safety elements, with the latter being preferred. The choice may be as simple as using all projects for which an as-built plan is received.

2. <u>Determine the critical data elements.</u> The State identifies which elements are most critical in terms of the timeliness of the data. It is important that this list include all critical elements, even if they are not on the as-built plan and must come from another source (e.g., AADT).

3. <u>Develop a supplemental file of date of data entry for each target project.</u> Assuming no date-of-entry is recorded in the State's inventory file, a supplemental file must be established that identifies each project by a unique reference number that can be related to the as-built plan and in which the date of data entry is recorded. The date of data entry should be the date on which the last critical element was entered. For example, if AADT is from another source and is obtained a week after all other elements are entered, the date of entry for this project would be the date on which the AADT data were entered in the file.

4. <u>Determine the open-to-traffic date.</u> For each project, the date on which the project was completed and opened to traffic must be determined. This information may have to be obtained from district staff or regional DOT offices.

5. <u>Calculate the measure.</u> At some time chosen by the State (e.g., at the end of the year), the number of days between the open-to-traffic date and the data entry date must be

calculated for each project. The State will decide whether to use median or mean number of days. Median will be less influenced by a few outliers with very long periods, but since these may be the projects of greatest interest (due to the longest delay), the mean number of days may be more appropriate.

6. Specify the performance goal. The initial calculation will provide a baseline for use in developing the improvement goal. Assume in this case that the mean number of days for year one is 45. The State can then decide whether the goal is to be percentage-based (e.g., reduce the mean days to entry by ten percent each year) or time-based (e.g., reduce the mean days to entry by five days each year). If more desirable, the State could establish a goal of percent of acceptable days-to-entry (e.g., a goal of 90 percent of days-to-entry being 30 days or less). The same data and procedure would be followed down to Step 5, the actual calculation of the measure.

7. Recalculate the measure each year. The same procedure would be followed each year to allow the State to chart its progress in reaching its goal. As is discussed below under Governance Practices, it will be important to further analyze the data to determine the cause of significant delays. In this case, the State would scrutinize those projects characterized by very long delays and attempt to determine why the delays occurred (e.g., a holdup in the delivery of the as-built plan).

ACCURACY

Definition

Accuracy is defined as *whether or not the information that is entered into the roadway inventory database is, in fact, a valid representation of what is found in the actual roadway environment.* Accuracy has aspects both internal and external to the data file.

Internal accuracy considers (1) the validity of the data (i.e., the codes entered are legitimate for that particular data element), (2) internal checks of consistency with other data elements, and (3) whether there are duplicate records for the same event (e.g., duplicate roadway sections). For some safety data elements, internal accuracy related to the legitimacy of the code can be tested by matching it with external sources (e.g., match a Vehicle Identification Number (VIN) with a national VIN file, match location coding with a statewide location database, etc.). Continuing with these examples, an indication that a VIN or roadway location within the roadway system has been matched through an external source does not necessarily mean that the VIN is accurate for the specific vehicle in the crash or that the roadway location noted is the exact location at which the crash occurred.

Internal accuracy checks can be computerized and thus automated. While checks for duplicate roadway segments may be simple, significant effort will be required to both identify other possible checks and to computerize them. These generally differ for each data element in the file. Such checks can include data type (e.g., character or numeric), data range (e.g., shoulder width between zero and 12 feet), and consistency with other variables (e.g., *shoulder width* with *curb presence*; *median width* with *divided/undivided*; or *ending milepoint* with *beginning milepoint* of the next roadway segment).

External accuracy focuses on whether the data are coded properly as determined by external sources or audits. As noted in both the CDIP Guide and the White Paper, external validity will require a special study or audit to answer questions such as, "*was the crash location correct?*" and "*is the reported shoulder width for this roadway segment the same as at the field location?*" For the roadway data, this will require some systematic review of data in the file versus field measurements or accurate as-built plans. Since this would not be possible for each variable in the entire file each year, it must be done on a sampling basis.

NHTSA Report Measures

The following measure and explanatory note is proposed in the NHTSA Report for roadway data accuracy:

- *R-A-1:* The percentage of all road segment records with no errors in critical data elements.
    - The State selects one or more roadway data elements it considers critical and assesses the accuracy of that element or elements in all of the roadway records within a period defined by the State.

Discussion

While the details are not specified, R-A-1 is an excellent measure of external accuracy—*are the critical data correct as compared to "ground truth"?* The topic of critical variables was discussed earlier under timeliness. For a roadway file, it would appear that three sources of ground truth information are available:

- *As-built plans* – If the user agency retains as-built plans, and if there have been no known modifications to a roadway section, then the information on the plans could be compared to the computerized data for the critical variables.
- *Photographic imagery* – It may also be possible to compare some critical variable data to information captured from videologs or aerial photographs. The data would have to be coded from these sources.

- *Field surveys* – If no other sources are available, field reviews of critical elements on a sample of locations could be conducted. Here, actual measurements would be taken – not as precise as survey data, but precise enough for comparison.

Because of the complexity and cost of such audits, it would be expected that ground truth data would be extracted or collected for a sample of roadway sections. This could be done based on roadway functional class (which would assure the inclusion of lower class roads, where data might be more questionable) within each highway district (which would include various terrains). Again, the user agency will need to design a plan for this validation effort.

Suggested Modifications/Additions

First, it is noted that R-A-1 refers to "road segment records." This may be confusing since MIRE and other documents use the term "segments" to only include longitudinal sections of roadway. Thus, segment record here should be broadly defined and should include records related to intersections, interchanges/ramps, and related inventories of traffic signals, guardrail inventories, etc.

The proposed measure is related to external accuracy—file data versus ground truth. It is also possible to develop one or more measures of internal accuracy. An example might be *the percent of critical roadway inventory elements whose attribute values are within reason-able ranges and/or are consistent with related variables*. This would require the agency to determine for each pertinent critical element the reasonable range (e.g., lane widths of eight to 13 feet, shoulder widths of zero to 12 feet, etc.) and whether there are related variables and, if so, what the logical relationship should be (e.g., if a curb is present, shoulder width would normally be zero; if median type is undivided, then median width should be zero or not applicable). This would lead to a set of computerized checks, which should be considered a desirable business practice.

Example Use in a Performance Goal

Recall that R-A-1 has been defined as *the percentage of all road segment records with no errors in critical data elements*. Assume a State wishes to incorporate R-A-1 into a performance goal. As noted above, this measure compares file entries to ground truth. A plan could be developed to assess the "ground truth" validity of all the agency's roadways over some determined period of time (e.g. 20 years- 5% of the system per year).

While the measure says "all segment records," the collection of ground truth data will usually be expensive. Thus, it is likely that only a sample of segments will be analyzed. The following steps appear to be necessary:

1. Determine critical data elements. The State decides which elements are most critical. (See the discussion under timeliness for general guidance.)

2. Determine a sampling plan. The objective here is to develop a measure that will characterize the accuracy of the full inventory file for the chosen elements. One idea would be to use a subset of those sample sections already chosen for HPMS, which would only be appropriate if the data on non-HPMS segments were felt to be equally accurate. The following should be considered in choosing the sample to be used:

   a. Since the quality of newly-entered data is likely to be high (e.g., the projects used in the timeliness example), it would be better to use roadway segments that are not new to the file.

   b. The State may be aware of variations in accuracy based on terrain, functional class, agency district, etc. If so, these different representative locations should be included in the sample.

   c. Roadway segments in inventory files are often homogeneous sections where the characteristics do not change, and these are usually short in length. Thus the collection of ground truth data in one-mile sections, for example, will include multiple homogeneous segments and thus multiple comparisons.

   d. In order to track this over multiple years, very similar segments should be chosen each year (e.g., select the adjacent mile or intersection as was selected the previous year).

   Perhaps the most important guidance is to choose a sample that can be repeated in future years, where costs are not prohibitive, and for which staff time will be available. The final sampling plan is likely to be based on what is learned from the first year's effort, i.e., how much can be sampled reasonably.

   For the purposes of this discussion, assume that the State has decided to capture one mile of data in each of the seven rural functional classes in three of their eight districts—one having level terrain, one rolling terrain, and one mountainous terrain. The one-mile sections will be chosen by placing a pin at the center of each district and choosing the one mile of highway in each functional class that is nearest that pin. (Other procedures could be used, including choosing HPMS sample sections if the selection criteria above are met). This will produce a sample of 21 miles in the State.

3. Determine sources of ground truth data. For each of the critical elements, the State will need to define the method of ground truth data collection. Since it will not be cost efficient to conduct surveys, alternatives would include scaling off measurements or extracting other data from aerial photographs (e.g., lane width, shoulder width, number of intersection legs, intersection skew, number of driveways by type, degree of curve, etc.) and from videologs (e.g., number of lanes, shoulder type, no passing zones, etc.). AADT data could be assembled from traffic count files and checked for logic with AADTs on adjacent segments.

4. Collect ground truth data. Using the sources found, ground truth data for each sample section will be collected. Care must be taken in assuring that the roadway being sampled is the same as the one in the file. There are times when the address variables describing a file section (e.g., route/milepost) may be in error. If so, all the comparisons will indicate error. Distance to nearby boundaries, intersections, or physical mile markers can often be checked either in the field or on videologs.

5. Calculate the measure. A supplemental file should be developed so that for each roadway segment in the inventory file, each critical variable has two measures: the inventory file measure and the ground truth measure. Differences between the two will then be calculated for each critical element. The State will decide on an appropriate acceptance level (e.g., lane width within 0.5 feet) and will code each element in each segment as either correct or incorrect. Using the measure as written, each segment will then be defined as correct if all elements are correct and incorrect otherwise, and the percent of the total number of segments tested that are correct will be calculated. (Note that an alternative measure would be the percent of all elements in the file that are incorrect).

6. Specify performance goal. The initial calculation will provide a baseline for use in the goal. Assume in this case that the percentage of correct records for year one is 60 percent. The State could then specify that the goal is to be percentage-based (e.g., increase the percent of correct records by five percent increments each year) up to a final goal (e.g., all critical variables are accurate in 90 percent of tested records).

7. Recalculate measure each year. The same procedure would be followed each year to allow the State to chart its progress in reaching its goal.

Note that while step-by-step guidance for the incorporation of the suggested internal accuracy measure (i.e., the percent of critical roadway inventory elements whose attribute values are within reasonable ranges or are consistent with related variables) is not presented here, examples of both ranges and pairs of related variables were presented earlier. Additional examples of inventory variables for which reasonable ranges could be established include route number, county and city codes, number of through lanes, median width, percent combination trucks, percent motorcycles, and speed limit. Examples of related variables for which logical relationships could be defined would include median barrier presence and median type, inner (paved) shoulder width and median type, and AADT ranges for the number of through lanes and functional class combinations.

COMPLETENESS

Definition

Completeness is defined as *having all required data elements (ideally accurate data) within the roadway inventory file for all required roads*. As noted in the CDIP Guide and the NHTSA Report, completeness also has internal and external aspects. *Internal completeness* considers whether all variables are recorded for each event or element (i.e., there are no missing or unknown data). *External completeness* looks at whether the data file contains all applicable events, sometimes tested by matching files or records between databases (e.g., matching injury crashes with EMS run reports).

For roadway inventory files, it appears that completeness has at least three major components:

- *Whether the existing inventory file includes records for all of the roadways targeted for analysis.* If the decision is made that all public roads are to be covered by various analyses, the completeness measure would be the percentage of targeted roads for which the inventory data are available. (While it may be a challenge for many agencies, it would not be impossible to earn high marks under this measure. For instance, Maine DOT includes all public roads in its inventory files.) If only State-system roads are needed in the analyses, then the measure would be related to whether newly-constructed State highways are entered into an existing database.
- *An external measure of whether all critical roadway inventory elements are included in the file layout.* As noted above, critical variables can be defined by the user with guidance from MIRE, HPMS, and other data sources.
- *An internal measure of how often coding for a specific data element field is missing.* The "missing data" concern is related to the issue of how to deal with "null" codes in the database, which includes entries such as "not available," "unknown," or "not recorded." While typically less of a problem for the roadway inventory database than for other databases (e.g., crash or injury), null codes remain an issue that must be addressed.

A null code is a legitimate response when the collectors of the information are unable to determine the specific value for a particular data element. However, it does not provide information that is usable by researchers. Perhaps the best approach to the issue of null codes is to monitor their frequency of occurrence within the individual elements in the database. When there is a high frequency of null codes, the State should investigate the elements in question to determine why the collectors of the data were unable to measure and or report on the actual values for the data elements. Based on the findings, it may be desirable to restructure the data element or provide additional training to the collectors to better enable them to report useful data.

NHTSA Report Measures

Listed below are the four measures for roadway completeness that were proposed in the NHTSA Report.

- *R-C-1:* The percentage of road segment records with no missing critical data elements.
  - The State selects one or more roadway elements it considers critical and assesses internal completeness by dividing the number of records that are not missing a critical element by the total number of roadway records in the database.
- *R-C-2:* The percentage of public road miles or jurisdictions identified on the State's basemap or roadway inventory file.
  - A jurisdiction may be defined by the limits of a State, county, parish, township, MPO, or municipality.
- *R-C-3:* The percentage of unknowns or blanks in critical data elements for which "unknown" is not an acceptable value.
  - This measure should be used when States wish to track improvements on specific critical data elements and reduce the occurrence of illegitimate null values.
- *R-C-4:* The percentage of total roadway segments that include location coordinates incorporating measurement frames, such as GIS basemap.
  - This is a measure of the overall completeness.

Discussion

Defined as *the percentage of public road miles or jurisdictions identified on the State's basemap or roadway inventory file*, R-C-2 involves an external measure of whether all pertinent miles are included in the file. It is the opinion of this author that this is a necessary metric, and the use of public road miles would be both better and easier than the use of jurisdictions. Total public road mileage is usually readily available, whereas a count of total possible target jurisdictions may be difficult to develop. In addition, the jurisdiction-based measure would lend equal weight to every jurisdiction, meaning that a very small jurisdiction could have the same effect on the measure as a much larger jurisdiction (e.g., a large city or even the full State highway system).

Additionally, as written, the measure includes reference to both a basemap and the roadway inventory file. It should be noted that the two could differ, as there could be a basemap containing certain roads (e.g., a spatial data map with some roads digitized) and an inventory file that may contain more, less, or the same attribute data as the basemap for all segments. Jurisdictions should be cognizant of the roads contained in the basemap and the critical elements for which information is being collected. R-C-3 is an internal measure of whether coding for the variables included is complete. Defined as *the percentage of illegitimate null values (i.e., blank or coded with "unknown" or another null code)*, R-C-3 appears to be both logical and understandable. The NHTSA Report note concerning "…for which unknown is not an acceptable value…" refers to possible cases where the variable is not pertinent for some specific set of roadway locations. While no examples were provided, the assumption is that the committee providing input to the NHTSA Report identified some examples of this scenario. This measure would be calculated for each element. It is also noted that while this variable refers to only critical elements, the State might wish to include all inventory variables in this analysis since it is relatively easy to calculate the percent blank or null for any variable in a computerized file.

FHWA's Highway Safety Information System (HSIS) has developed a computerized check of the percent of null records (i.e., uncoded (blank), "not stated" or "unknown") within each element of every file (i.e., crash, roadway inventory, intersection, etc.). This check is conducted each year when new files are received from the participating DOTs. The output provides the name of the file, the name of the variable/element and the percent blank for every element with five percent or more null records.

R-C-4 appears to be a measure of a State's progress in moving to a spatial data (GIS) platform. Since no additional clarification is provided, it is not clear how it differs from the part of R-C-2 that refers to "the percentage of public road miles identified on the State's basemap," unless "basemap" there does not refer to a GIS map. R-C-4 refers to "percent of total roadway segments." Again, no definition of segment is provided, and it is not clear how a user would count the total number of possible segments (i.e., the required denominator) if they are not already mapped. A count of total public road mileage is more likely to be available (this information is reported annually in FHWA's Highway Statistics Report). It is also noted that the measure refers only to the inclusion of coordinates and not to the inclusion of other attributes. Finally, since the measure does not refer specifically to a State's spatial data system, it could be interpreted as requiring a count of all segments (or miles) that are in both the State's spatial data system and all spatial data systems created by local agencies. Thus, without further clarification, it is difficult to know the intent of this measure or how it differs from R-C-2.

Suggested Modifications/Additions

In summary, revisions to the above have been recommended:

- *R-C-1 (original):* The percentage of road segment records with no missing critical data elements.

  No revisions to R-C-1 have been proposed.

- *R-C-2 (original):* The percentage of public road miles or jurisdictions identified on the State's basemap or roadway inventory file.

  No revisions to R-C-2 have been proposed.

- *R-C-3 (original):* The percentage of unknowns or blanks in critical data elements for which "unknown" is not an acceptable value.

  No revisions to R-C-3 have been proposed.

- *R-C-4 (original):* The percentage of total roadway segments that include location coordinates incorporating measurement frames, such as a GIS basemap.

  R-C-4 (revised): Under R-C-4 (original) roadway segments should also be considered to include intersections and interchanges/ramps

R-C-1 appears to be related to the external measure concerning whether all critical variables are included in the file layout for the existing file. R-C-1 is seemingly element-based and focuses on whether all critical elements are present in the file layout and, therefore, supposed to be coded. (Note that this measure apparently does not relate to what percentage of records has legitimate codes, since this is covered in R-C-3.) Because the measure is related to the number of segments, it concerns only those roadways that are currently in the inventory file; thus, if a database covers only State-maintained roadways, then local roadway systems will be disregarded by the measure, since a count of segments would not exist for those roadways.

An additional measure which could address whether or not critical elements are included in the roadway file layout could be written as follows:

- *R-C-5:* The percentage of critical elements included in the roadway file.
  - The State selects a set of roadway elements it considers essential and assesses completeness by dividing the number of critical elements in the file layout by the total number of critical elements the jurisdiction considers to be necessary.

If the intent of R-C-2 is to measure how much of the total public road mileage is included in the State's GIS mapping, an additional performance measure to consider might be written as follows:

- *R-C-6:* The percentage of total public road mileage that is included in the State's geospatial data system.
  - "Included" here refers to the presence of usable location coordinates and not to the presence of other attributes for each mapped segment.

The FHWA Offices of Highway Policy Information and Planning, Environment, and Realty jointly released a Guidance Memorandum in August 2012 announcing that the HPMS Field Manual had been revised to require that all public roads be covered by each State's linear referencing system network. This was an expansion of the previous requirement that only roads eligible for Federal Aid had to be included in the LRS. It is expected that each State will be compliant with this latest requirement by the time it submits its 2013 HPMS data, which will be due in June 2014 *(9)*.

Example Use in a Performance Goal

The calculations of performance measures for R-C-1through 6 are relatively straightforward, so individual steps will not be presented here.

The two general performance measures for completeness deal with 1) the inclusion of critical data elements which are populated with correct values into the State's roadway inventory database, and 2) the completeness of the basemap used to uniquely identify the geospatial locations of roadway segments, intersections and interchanges/ramps onto which the critical data elements are overlaid. Therefore, the two general forms that the performance goals for the measures identified in the Completeness Section may take are as follows:

1. A general targeted annual percentage increase in the number of critical elements included within the file layout; e.g., increase the number of captured critical elements by ten percent each year.

2. A series of specific percentage targets over multiple years; e.g., if 50 percent of the critical elements is included in the dataset in the baseline year, then the goal could be 70 percent in year two, 85 percent in year three, and 100 percent in year four.

3. A general targeted annual increase in the number of roadway locations included in the basemap onto which the data elements will be overlaid; e.g. increase the number of locations identifiable in the basemap by ten percent each year.

4. Similar to performance goals in item 2, a series of specific percentage increases in the inclusion of roadway locations into the basemap over multiple years, would constitute performance goals for the inclusion of roadway locations to the basemap. The ultimate performance goal would, of course, be the inclusion of all road segments, intersections and ramps in the State's basemap.

UNIFORMITY

Definition

Uniformity is defined as *the degree to which the data elements that are collected conform to standard or common definitions and attributes, and to which the definitions and attributes are the same across all geographic areas and across files developed at different points in time.*

As noted in the CDIP Guide and the NHTSA Report, uniformity has both external and internal aspects. Externally, data collection procedures and data elements should agree with nationally accepted guidelines and standards (e.g., crash elements agreeing with elements in MMUCC). For roadway inventory files, this might imply that the data, or at least the critical elements, are consistent with MIRE definitions and attributes for those elements. Uniformity with MIRE could have two aspects: (1) the percentage of MIRE elements that are included in the State file (which might also be considered a completeness measure), and (2) for MIRE elements that are present in the State file, their level of consistency with comparable MIRE elements in terms of variable names, definitions, and coding.

There would appear to be two internal uniformity aspects for roadway data, one related to consistency across *space*, and the other related to consistency across *time*. With respect to consistency across space, all jurisdictions within a State should collect and report the same data using the same definitions and attributes. Most State-system roadway inventory files are uniform across the entire State. However, if local inventory files are incorporated into a State inventory system, uniformity of elements and element-coding could be a significant issue.

There would also appear to be two aspects of uniformity for roadway inventory files with respect to time: (1) the consistency in coding of a given *element* across years (due to either official changes or unofficial changes introduced by different data collectors), and (2) the consistency in coding of a given *location* across years (i.e., whether the same point on the roadway has the same address [e.g., milepost] over a multiyear period). Both are important because many safety analyses look at data from multiple years. The concerns over tracking a particular location over multiple years arise in a linear-referencing system when a section is lengthened or shortened through reconstruction activities, which affects all mileposts downstream of the change to the roadway.

NHTSA Report Measure

The following measure is proposed in the NHTSA Report for roadway uniformity:

- *R-U-1:* The number of MIRE-compliant data elements entered into a database or obtained via linkage to other databases.

Discussion

This lone measure relates to external uniformity. If the goal is to provide information concerning the degree to which MIRE elements are included, this author would suggest the use of "percent" rather than "number." Previous NHTSA documents defined this measure in terms of number *or* percent of MIRE elements comprised in the State file and included a supplemental note indicating that States could also consider comparisons with MIRE code values and attributes. This final measure does not clarify the term "MIRE-compliant," leaving it up to the user to decide whether uniformity only involves the presence of an element or also involves comparison with MIRE definitions and coding.

Suggested Modifications/Additions

It is desired that all States move toward uniformity with the MIRE elements, and R-U-1 is a sound measure of that shift. Alternative external measures related to MIRE might include individual measures for each of the three categories of descriptors used in MIRE (i.e., segment, alignment, and junction descriptors) or for selected subcategories within each major category (e.g., segment cross section, segment traffic flow data, etc.). This author would suggest that the two most important components of MIRE not currently collected by State DOTs are *junction/intersection files* and *horizontal curvature files*. Both types of variables are critical to the analyses of two of the more important crash types—intersection-related crashes and roadway departure crashes. Measures could be established for the percentage of MIRE intersection or MIRE horizontal curvature elements collected and entered into the State roadway inventory file.

Since R-U-1 does not address what has been described above as internal uniformity, it is suggested that the following measure be added:

- *R-U-2:* Percent of critical roadway elements in all inventory files whose names, definitions, and coding are uniform across the target roadway system (care should be taken in reporting to assure uniformity between jurisdictions).

This performance measure has two primary focus areas: (1) uniformity between State-system data elements that come from various offices of the State DOT (e.g., various District, Division, or Regional offices), and (2) uniformity between data elements from the State system and various local roadway systems. Although achieving consistency may require a significant level of effort for the recoding of data variables, maximizing the reach and effectiveness of safety analyses will require consistency in variable naming and coding for data from all contributing datasets, including the base inventory file, railroad grade crossing file, the bridge index, asset management files, etc.

A rigorous before-after evaluation of the safety effectiveness of a given countermeasure typically requires several years of data spanning the time before and after the installation of the treatment of interest. To monitor the quality of the data required for these multiyear analyses, the uniformity measures must place an emphasis on the two main time-related concerns noted above:

- *Uniformity in inventory data coding across time*. The first goal is to define methods that help to identify possible coding changes from one year to the next and then to recode the file such that multiyear analyses can be done; that is, one must ensure that codes across the entire time period of interest mean the same thing.
- *Uniformity in location coding across time*. The second goal is to insure that analyses aimed at examining the same locations over multiple years are indeed doing so. Has the specific address (e.g., milepost) of a point along a roadway changed, perhaps due to realignment of the roadway? Has a referencing system been modified or replaced during the study period? If so, is there a method to trace the same roadway location across the multiple referencing systems and all years of interest?

Rather than define measures, each of these goals is discussed further as a "business practice" in Chapter 3.

Highway Safety Information System (HSIS) Data Consistency Check

For each variable in each data file it receives each year, HSIS runs a computerized check for consistency between variable codes in the new data versus data from the previous year. The check compares the column percentages for each code in each variable and prints out those for which the difference exceeds certain limits. For example, as shown in Lines 21-25 below, there were large differences in each functional class category between 2006 and 2007 data. (See the final two columns for percentages.) These differences resulted from a large percentage increase in the number of uncoded records (i.e., blank codes, as shown in Line 21). Subsequent discussions with the State data office led to a correction. In the final two rows of the table related to whether the crash was a hit and run crash, the large shifts in percentages indicated that the yes/no codes had been erroneously reversed in 2007.

	A	B	C	D	E	F	G	H
1	**Obs**	**varname**	**cvalue**	**_LABEL_**	**flag**	**check**	**_06**	**_07**
2	**1**	None	Blanket check			Total number of obs is < 10 %	194638	203492
3	**2**	cause1	NOT APPLICABLE	Percent of Column Frequency	2a	#2a: Missing/unknown >= 5%	10.71	10.4
4	**3**	cause2	NOT CODED	Percent of Column Frequency	2a	#2a: Missing/unknown >= 5%	7.53	0
5	**4**	cause2	NOT APPLICABLE	Percent of Column Frequency	2a	#2a: Missing/unknown >= 5%	51.8	56.14
6	**5**	city		Percent of Column Frequency	2a	#2a: Missing/unknown >= 5%	16.69	16.86
7	**6**	divided	UNKNOWN	Percent of Column Frequency	2a	#2a: Missing/unknown >= 5%	31.31	31.22
8	**7**	func_cls		Percent of Column Frequency	2a	#2a: Missing/unknown >= 5%	0	21.95
9	**8**	rd_def	UNKNOWN	Percent of Column Frequency	2a	#2a: Missing/unknown >= 5%	26.3	26.04
10	**9**	func_cls		Percent of Column Frequency	2b	#2b: Missing/Unknown increase > 12%	0	21.95
11	**10**	rd_def	OTHER	Percent of Column Frequency	2b	#2b: Missing/Unknown increase > 12%	0.2	0.27
12	**11**	rdsurf	OTHER	Percent of Column Frequency	2b	#2b: Missing/Unknown increase > 12%	0.12	0.15
13	**12**	tc_cond	OTHER	Percent of Column Frequency	2b	#2b: Missing/Unknown increase > 12%	0.47	0.52
14	**13**	tot_inj	ERROR CODES	Percent of Column Frequency	2b	#2b: Missing/Unknown increase > 12%	0	0
15	**14**	totcinj	ERROR CODES	Percent of Column Frequency	2b	#2b: Missing/Unknown increase > 12%	0	0
16	**15**	cause1	NOT CODED	Percent of Column Frequency	3a	#3a: column % change of >= 12% and a row total > 1%	2.21	0
17	**16**	cause1	WEATHER	Percent of Column Frequency	3a	#3a: column % change of >= 12% and a row total > 1%	2.54	4.2
18	**17**	cause1	EXCEEDING SAFE SPE	Percent of Column Frequency	3a	#3a: column % change of >= 12% and a row total > 1%	2.21	2.97
19	**18**	cause2	NOT CODED	Percent of Column Frequency	3a	#3a: column % change of >= 12% and a row total > 1%	7.53	0
20	**19**	cause2	EXCEEDING SAFE SPE	Percent of Column Frequency	3a	#3a: column % change of >= 12% and a row total > 1%	1.5	1.99
21	**20**	func_cls		Percent of Column Frequency	3a	#3a: column % change of >= 12% and a row total > 1%	0	21.95
22	**21**	func_cls	OTHER PRINCIPAL AR	Percent of Column Frequency	3a	#3a: column % change of >= 12% and a row total > 1%	54.77	41.1
23	**22**	func_cls	MINOR ARTERIAL (UR	Percent of Column Frequency	3a	#3a: column % change of >= 12% and a row total > 1%	21.56	15.11
24	**23**	func_cls	COLLECTOR (URBAN)	Percent of Column Frequency	3a	#3a: column % change of >= 12% and a row total > 1%	7.54	5.34
25	**24**	func_cls	LOCAL ROAD OR STRE	Percent of Column Frequency	3a	#3a: column % change of >= 12% and a row total > 1%	0.68	2.39
26	**25**	hit_run	NO	Percent of Column Frequency	3a	#3a: column % change of >= 12% and a row total > 1%	12.11	89.21
27	**26**	hit_run	YES	Percent of Column Frequency	3a	#3a: column % change of >= 12% and a row total > 1%	87.89	10.79

Example Use in a Performance Goal

Assume a State wishes to incorporate a version of R-U-1 into a performance goal. The State defines uniformity in terms of the presence of the same variable in both the State's basic roadway inventory file and the MIRE listing, with the definition of the variable being the same in each, regardless of whether the variable names or coding are identical in both files. Further assume that the State has compared data elements in its file with the 61 MIRE elements in the segment location/linkage list, the segment classification list, and the segment cross section list and learned that, for the State system, only two of the 52 critical variables in MIRE are missing. The State considers this to be adequate coverage and has thus chosen to define a measure concerning uniformity with the MIRE elements related to at-grade intersections on State-system roads. The State wishes to ultimately include both the general-descriptor variables related to the entire intersection and those variables collected for each approach. The following steps appear to be necessary:

1. Define the measure. The State defines its roadway uniformity measure as follows:

    - *R-U-1:* The percent of critical MIRE data elements related to at-grade intersections entered into the basic inventory file for State-system roads.

2. Determine the target data elements in MIRE. There are 58 intersection-related elements in the MIRE listing, 43 of which MIRE deems "critical" for analytic tools such as SafetyAnalyst or IHSDM While some of the additional 15 value-added elements may be incorporated into the inventory file, the State has decided that the measure and performance goal will concern only the 43 critical elements.

3. Determine the MIRE-compliant elements in the inventory file. As noted above, the State considers a variable to be MIRE-compliant if its definition matches the MIRE definition (i.e., the codes do not have to match). The State will examine the definitions of each of the 43 critical MIRE elements and determine which are present in the State inventory file. This examination may reveal some variables in other inventory files but not yet in the State intersection file (e.g., route/milepost data on crossing routes may be available in the spatial data file; information on intersection traffic control may be available in a separate traffic signal file). These elements would not be counted as present in the base year but could be added in the subsequent years.

4. Calculate the measure. The measure will be calculated by dividing the total number found in the current State file by 43, the number of critical MIRE elements.

5. Specify the performance goal. The initial calculation will provide a baseline for use in the goal. Assume in this case that the number of critical MIRE intersection variables for year one is 15, so the calculated baseline measure is 35 percent. The State could then

decide that it wishes to include all 43 elements within the next four years and then specify that the goal for each subsequent year is the addition of seven elements each year. Thus, the yearly proportion of critical elements is as follows:

- *Year two goal* – 51 percent of all critical elements.
- *Year three goal* – 67 percent of all critical elements.
- *Year four goal* – 83 percent of all critical elements.
- *Year five goal* – 100 percent of all critical elements.

6. Recalculate measure each year. The same procedure would be followed each year to allow the State to chart progress in reaching its goal.

INTEGRATION

Definition

Integration is *the ability to link the data records in one database with common or related records in another database*. Such linkage among databases provides a richer source of information on which to conduct analyses. Because integration is based on the relationship between multiple individual datasets, it is unique from the other performance attributes in that it always involves two or more traffic records systems. When devising measures for integration, the focus may range from *macro*—the number of databases that can be linked to a particular database—to *micro*—the number of individual records from one file that can be linked to the individual records of another.

Once a State has demonstrated the ability to integrate databases, this author would recommend the use of the *micro* measures (i.e., those that examine the linkage of individual records). Files that utilize the same location referencing system (e.g., GIS or linear-referencing system) may be considered "linkable," but a substantial number of individual records may not be directly relatable to one another if there are errors in the linkage variables of either file. This points to the fundamental question of when two files can be declared truly "linkable"—when they have the same *location address system* (e.g., milepost or latitudinal/longitudinal coordinates), or when some *percentage of the records* are linkable? Both these issues seem to point to micro-based measures that are based on the percentage of records that can be linked.

NHTSA Report Measures

The following is proposed in the NHTSA Report:

- *R-I-1:* The percentage of appropriate records in a specific file in the roadway database that are linked to another system or file.
    - For example, a State may wish to determine the percentage of records in the State's bridge inventory that can be linked to the basemap file.

Discussion

Integration is needed both between different inventory files (e.g., the basic roadway inventory file and the bridge file) and between roadway inventory files and non-roadway inventory files in the other five core databases (e.g., the crash file). The proposed measure is general in nature, leaving it up to the user to determine which pairs of specific files should be analyzed. The same measure (i.e., percentage of records that is linkable) would be used for each of the pairs of files.

From the perspective of safety analyses, the most important pair of databases includes the basic roadway inventory file and the crash file. Linkability between these datasets is critical to safety analyses incorporating both traditional measures and newer tools that are used to support the State's HSIP. At the next level of importance would be linkages between the basic inventory file and other inventory files containing variables needed for safety analyses (e.g., bridge database, traffic control device database, etc.). The user would need to identify each inventory file that contains critical safety variables and analyze the degree of linkability between it and the basic inventory file. The following are example data elements required by the Highway Safety Manual, IHSDM, or SafetyAnalyst that are often not contained within the basic inventory files (but may be in other datasets):

- Horizontal curve data.
- Grade information.
- Number of legs at an intersection, and the milepost on the minor road.
- Minor road AADTs (perhaps in files from local jurisdictions).
- Driveway counts within categories.
- Centerline rumble strip presence.

More information concerning what is required by these tools is in Appendix B of the MIRE report *(1)*.

Suggested Modifications/Additions

None other than those noted above.

Example Use in a Performance Goal

Assume a State wishes to develop performance measures and goals related to the integration of the crash file and its basic roadway inventory. It has been decided that two measures will be developed:

1. The degree to which total reported crashes can be linked to the roadway inventory file.
2. The extent of linkage of roadway inventory data to crashes occurring on roadways already included in the inventory file; for many State DOTs, this would be all State-system roads.

The first performance measure will provide information on the ultimate goal of establishing a statewide inventory file that is linkable to all crashes. The State understands that this measure is controlled by two factors: (1) the completeness of its roadway inventory file (i.e., what portion of total State mileage is included in the inventory file), and (2) the accuracy of the linkage information in each file. Using automatic linkage procedures already in place, the State will attempt to link all crashes for the base year with the existing inventory file, and the measure will be the percentage that can be linked. Additional analyses could bring to light any possible impediments to the overall integration, which may include the following:

- Crashes were not assigned a location address (e.g., route/milepost, latitudinal/longitudinal coordinates, etc.) due to a lack of location descriptors.
- Each crash was assigned a location, but the location did not match any segment in the inventory file.

The initial calculation will provide a baseline for use in the specification of a performance goal. Assume in this case that roadway inventory data may be linked to 55 percent of reported crashes. Assuming there is an ongoing effort to increase the roadways covered in terms of crashes mileposted and roadway inventory data available, the State could then adopt a goal that is percentage based. For example establish a performance goal to increase the proportion of linked crashes by increments of five percent each year. For this example it would yield 60 percent linkage in year two, 65 percent in year three, and so on.

The second measure concerns only crashes on State-system roads and is related primarily to the accuracy of the linkage information in the crash and roadway inventory files. This measure will involve more effort, as the crash records being tested should only include those that can possibly be linked with the existing inventory file (i.e., only those crashes on State-system roads). The following steps appear necessary:

1. Specify which roadways included in the inventory file are to be tested. This will perhaps be the most difficult step in that the crash data may or may not include variables that will allow one to determine whether the crash could possibly be linked. Note that the goal is to test all crashes that could *potentially* be linked, including crashes that occurred on pertinent roadways but did not have adequate location information. Assume that the State's roadway inventory file includes all Interstate, U.S., and State-numbered highways and some secondary roads. Since the identification of potentially-linkable crashes on secondary roads would essentially require a full address (i.e., route and milepost), an option would be to select only those route types that are completely covered in the inventory file—in this case, Interstate, U.S., and State-numbered routes. Assuming that the "route type" part of the address is coded for all crashes, crashes not occurring on these routes could be screened out, leaving only the potentially-linkable ones.

2. Calculate the measure. At a time chosen by the State—possibly the date at which the year-end crash file is finalized—attempt to link all potentially-linkable crashes with the basic inventory file. Calculate the measure by dividing the number of crashes linked by the total number of potentially-linkable crashes (i.e., the total number of crashes on Interstate, U.S. and State-numbered highways).

3. Specify the performance goal. The initial calculation will provide a baseline for use in the goal moving forward. Assume in this case that 80 percent of potentially-linkable crashes were actually linked to the appropriate roadway inventory data. The State can then decide to increase that percentage by five percent each year, with a final target goal of 95 percent linked (i.e., 85 percent at the end of year two, 90 percent at the end of year three and 95 percent at the end of year four). Note that this percentage will not increase without additional efforts to determine the cause of non-linkage (e.g., errors in the inventory files, errors in original data reported by law enforcement, errors in crash location even with sufficient police data, etc.) and efforts to correct the problems identified.

4. Recalculate the measure each year. The same procedure would be followed each year to allow the State to chart the progress in reaching its goal.

ACCESSIBILITY

Definition

Accessibility concerns *the degree to which data or information from the data files are readily and easily available to legitimate users*. As noted in the NHTSA Report, accessibility is a measure of customer satisfaction. Accessibility can apply to both individual records and to either periodic reports or report-generating tools. The following discussion will concern the accessibility of the data itself.

It would appear that the specification of accessibility measures is dependent on the data agency's customer service goals. Two slightly different goals emerge:

- <u>Goal 1:</u> Make data accessible to legitimate users in an easy and timely fashion.
- <u>Goal 2:</u> Make data accessible to legitimate users in an easy and timely fashion, and provide additional data-related assistance and marketing to increase data usage.

The first goal is related to providing existing data to rightful and appropriate users. The second goal builds upon the first by also encouraging and assisting in the use of the data in order to increase the number of users. Measures for the first goal would the ease of data acquisition from those who request and obtain the data. Measures for the second goal would include these but also add measures of increases in data request. This suggests that an inventory data program should not only emphasize making the data accessible, but it should also look to market the data to potential users and provide customer service resources (e.g., a helpdesk) to simplify and accommodate an efficient use of the data. Note that the CDIP Guide suggests that marketing crash data is part of accessibility, so the number of users would be a logical measure.

Monitoring the use of inventory data by key customers may be a necessary part of a State's overall inventory program if use by others is important. For example, the Kentucky Transportation Cabinet has a program in which updated intersection AADT and other inventory information for State-system and higher-order county roads are provided annually by local development districts under a contractual arrangement. Under this arrangement, a valid measure for Kentucky might be the percentage of such districts that access the data on a regular basis.

Use of data by others is a key component of a sound program, not only because the data are developed with public funds and thus should be available to others, but also because use by others will provide important inputs to the owner agency concerning issues and problems that

should, and can, be corrected. This is discussed further in Chapter 3 under "Business Practices." The important issue is not just data accessibility but whether a goal of the agency is to increase usage. If this is the case, then the increases in the numbers of users is an important performance
measure.

Washington State DOT Video Log Data

WSDOT has made their State-system roadway video log available to the public at their Transportation Data web page (see http://srview.wsdot.wa.gov/). The user can select a region, find a specific route, and either "drive" the route or find a specific location based on information provided on the screen. A forward facing, right side and 360-degree view are available.

NHTSA Report Measures

The following measure and explanatory note for roadway data accessibility is proposed in the NHTSA Report:

- *R-X-1:* To measure accessibility of a specific file in the roadway database: Identify the principal users of the file. Query the principal users to assess (a) their ability to obtain the data or other services requested, and (b) their satisfaction with the timeliness of the response to their request. Document the method of data collection and the principal users' responses.

The NHTSA Report then refers to an earlier general discussion concerning accessibility and makes the following key points:

1. R-X-1 is for each database (and thus might be used repeatedly for the multiple inventory databases).
2. The data manager determines who the legitimate principal users are—who is the best judge of data accessibility?
3. The principal users would then be queried to assess whether they received the necessary data and if the data were delivered in a timely fashion.
4. The data manager would then document the system or method used in the query and the principal users' responses.

Two example survey methods are provided. In the first, the principal users are surveyed on an annual basis, and they provide information on applicability of the data they received, timeliness of the response, etc. The data manager then reviews these inputs and classifies them as positive, neutral, or negative, and the measure is the percentage positive (or negative) of all responses. In the second example method, the manager reaches out to each user within two days of data delivery and asks questions concerning whether the requested data were received and if the user was satisfied with the speed of the response; sample answers to both questions include "*yes,*" "*for the most part,*" "*partially,*" and "*no*."

Discussion

The accessibility measure changed more through the NHTSA developmental process than did any other measure. Earlier versions had specific measures including number of users requesting and receiving data, number or percentage of authorized users requesting and receiving data, and the percentage of requests filled within the agency's defined timeline. As indicated above, the earlier measure involving the numbers of users are more appropriate for a data agency who desires to continually increase usage of its data. The current measure appears to be related to goal one above—providing good access to the data but not necessarily increasing usage.

The NHTSA Report also indicates that the suggested measure would be best used to gauge the impact of an improvement to a data system (presumably an improvement that makes it easier to extract and distribute data). This would be done by surveying principal users before and after the rollout of a specific upgrade that would "provide the most meaningful measure of improved database accessibility." However, improved (or acceptable) accessibility should be a continuing goal, not just one measured with system changes.

Suggested Modifications/Additions

The measures noted are sound, although it does appear to be more appropriate for a data agency whose principal goal is to provide existing data to primary users rather than to increase data use. For agencies that also wish to increase use, the following is a possible supplemental measure:

- *R-X-2:* Number of users receiving information from the inventory file.

This author would also suggest modifying the part of the NHTSA example related to whether the data were received in a timely fashion. The example measure suggests asking whether the user was satisfied with the speed of the response, with possible responses being "*yes", "for the most part", "partially,"* and *"no*." Since this leaves "acceptable speed" as a subjective judgment that can differ from user to user, it might also be good to include a supplemental question concerning the amount of actual time between submission of the request and receipt of the data. Or, if the agency has a defined goal for responding to a request, an additional measure could be established as follows:

- *R-X-3:* Percent of requests received for information or data from the State roadway inventory file that were filled within the State's defined timeline.

Note that this measure can be generated without the user survey if the agency tracks the date the request is received and the date the data are sent out.

Finally, it is suggested that if a user survey is used, it should include at the end a free-form request for suggestions for improving accessibility.

Example Use in a Performance Goal

Assume a State wishes to incorporate the procedure specified in R-X-1 above in order to define the following two-part measure:

- *R-X-1:* The percent of internal and external roadway inventory data requestors who judged (a) the data received to be what was requested, and (b) the timeliness of the response to be acceptable.

The State wishes also to use the survey to obtain feedback from users on possible improvements to its data and data distribution systems. Knowing that surveys are often declined or ignored, the State has also decided to develop the following (non-survey) companion measure:

- *R-X-2:* Percent of requests received for information or data from the State roadway inventory file that were filled within two weeks of receiving the request.

The State has also decided that, at this point, only the accessibility of the basic inventory file data is to be tested and that, rather than limiting the measure to requests from only principal users, any request that can be answered (e.g., there may be requests for data that do not exist) will be included in the process. The following steps appear to be necessary:

1. <u>Establish a request documentation system.</u> Requests for data may be received in different formats (e.g., phone, mail, email, webpage contact, memo from another agency or department, etc.) and by different people (e.g., data manager, data staff member, etc.). A system (perhaps spreadsheet-based) should be established that records for each request the following information at a minimum:

    a. Requestor name and contact information.

    b. Date request was received.

    c. Specifics of request (often in narrative form).

    d. Person to whom request was assigned (i.e., staff member responsible).

    e. Date data or information were sent out.

    f. Comments; e.g., notes on each follow-up contact necessary to complete the request. (Contacts are often needed to clarify the request.)

2. <u>Determine time of survey.</u> As noted above, the survey can be done at the time of data distribution or at some established time (e.g., annually). The advantages of surveying at the time of distribution include better recall of both satisfaction and timeliness and the fact that the survey can be included with the data, which may represent a time when the

requestor may be more likely to respond. Periodic (e.g., annual) surveying would provide an overall average rating from principal users who submit multiple requests each year and may provide more useful inputs as to how the data and delivery systems can be improved. For our example, the State has decided to survey at the time the data are delivered.

3. Develop survey method. The data manager will need to determine how the survey is to be distributed—by phone, mail, email, or some combination thereof. The State has decided that, since the majority of requests are now filled via email or through downloads from their website, email will be the primary survey delivery method.

4. Develop survey form. The NHTSA Report provides details concerning what information might be requested and example questions that might be asked. The box below shows one example survey incorporating some of these suggestions.

5. Follow up with non-respondents. Because low response rates to surveys are the norm, obtaining a higher response may require that the State resend the survey with a reminder note at some point after the data are distributed or after the annual survey is distributed. This will require that the State either send a reminder to each data recipient (e.g., two weeks after the date of data delivery, including a note saying, "Disregard this reminder if you have responded,") or to only those who have not responded. While the latter is better customer service, it will require the development of a response tracking system. The date that the response is received could be captured in the request documentation system described in Step 1 above.

6. Calculate the measure(s). At least annually, the data manager or person responsible for this effort will compile the survey responses and calculate the percentages within each category of each response and summarize the non-categorical responses (e.g., calculate the number of responses with over 21 days between request and data delivery; list and summarize suggestions for improvements). The second measure related to percent of requests filled with a given time period can be calculated directly from the request documentation system described in Step 1 above.

7. Specify the performance goal(s). The State's system can be used to define three different goals: (1) the percentage of responders fully satisfied with the data received, (2) the percentage of responders who were fully satisfied with the timeliness of the response, and (3) the percentage of requests satisfied (from the internal system) within two weeks. The State could then specify three different performance goals. The initial calculation will provide a baseline for use in each goal. Assume, for example, that the percentage fully satisfied with the timeliness of the data delivery was 70 percent. The State can then decide to increase that percentage by five percent each year, with a final

target goal of 95 percent satisfied (i.e., 75 percent at the end of year two, 80 percent at the end of year three, etc.). Note that the suggestions received may provide information on both the problems and the potential solutions.

8. Recalculate the measure each year. The same procedure would be followed each year to allow the State to chart the progress in reaching its goal.

Dear DOT Customer,

You recently requested roadway inventory data from the (State X) DOT Information and Technology office. Please take a few minutes and respond to the following questions. Input from customers like you will help us to improve our program.

1. Did you receive the data, information, or assistance that you requested?

__ Yes

__ No (If "No", stop here and send reply).

2. Were you satisfied with the data? Was it what you needed?

__ Yes, fully satisfied

__ Yes, satisfied for the most part

__ Only partially satisfied

__ Not satisfied

3. Approximately how many days did it take us to respond to your request?

(Enter number of days here: ________)

4. Were you satisfied with the speed of the response to your latest request?

__ Yes, fully satisfied

__ Somewhat satisfied

__ Not satisfied

5. Do you have any suggestions concerning how we can improve our data or our data delivery system?

If you wish to discuss your experience with one of our staff, please call xxx-yyy-zzzz.

Thank you!

CHAPTER 3: MEASURE-RELATED BUSINESS PRACTICES

The preceding discussion has detailed specific roadway inventory metrics whose regular use can provide insight into the health of the inventory system and the issues and problems that need to be addressed. Clearly, the regular review of these measures without follow-up problem-correction efforts is of little value to a data agency. The purpose of this section is to enumerate business practices that may help to improve the correction process. Many of these practices are either in use in State roadway inventory agencies or have been suggested in other data-related discussions.

ESTABLISH/IDENTIFY A ROADWAY INVENTORY LEADER

Roadway inventory systems are usually comprised of multiple files with multiple owners. Placing a single person in charge can enhance coordination among the owners and ensure that the necessary modifications are made. The job description of the roadway inventory leader should be clearly defined, and the position should include adequate support in both staffing and funding. The term "leader" is used rather than *coordinator* (since the job will include, but not be limited to, coordination) or *czar* (since this person is not likely to officially oversee all other inventory data owners). This leader should be a permanent member of the State's Traffic Records Coordinating Committee (TRCC).

Based on the experience of State agencies around the U.S. who have superior inventory data, this person not only needs to be a leader, but also a *champion*—someone with a passion for the expansion and enhancement of roadway inventory data.

ESTABLISH AN INVENTORY COORDINATING COMMITTEE

The TRCC should help a State to meet the coordination needs of all traffic records efforts and systems. A suggested subcommittee of the TRCC would be an Inventory Coordinating Committee. The Inventory Coordinating Committee would focus exclusively on inventory data. It would have membership representing each of the various existing inventory files (e.g., basic roadway inventory, pavement management, asset management, etc.) and a representative of the information technology group or GIS group who works with the different types of inventory data. The committee would meet on a regular basis, with the inventory leader and his or her staff responsible for setting an agenda, calling the meeting, and recording and distributing meeting minutes.

ESTABLISH ROADWAY INVENTORY MEASURES

The inventory committee and leader should establish a set of measures that will assist in the management of the inventory system. Two or more are suggested for each of the six performance attributes described above. If the measures posed in Chapter 2 are used, the committee will also have to address the noted corresponding issues (e.g., *number* versus *percentage*, whether separate measures are needed for the inventory data versus the basemap, etc.).

CALCULATE THE MEASURES REGULARLY

The leader and staff would be responsible for the regular (e.g., annual) calculation of each of the measures and reporting to the committee and other pertinent parties like the State TRCC.

CONDUCT PERFORMACE MEASURE RELATED FOLLOW-UP ANALYSES

As noted above, many of the measures will help to identify the basic nature of issues or problems in the inventory system, such as unacceptable levels of missing data, or a failure to link specific files. However, the performance measures will not produce the level of information needed to define the problem in the detail required to allow for correction, and additional analyses will be needed. These would primarily be the responsibility of the inventory leader and staff but may require the participation of other owner-agencies, as well.

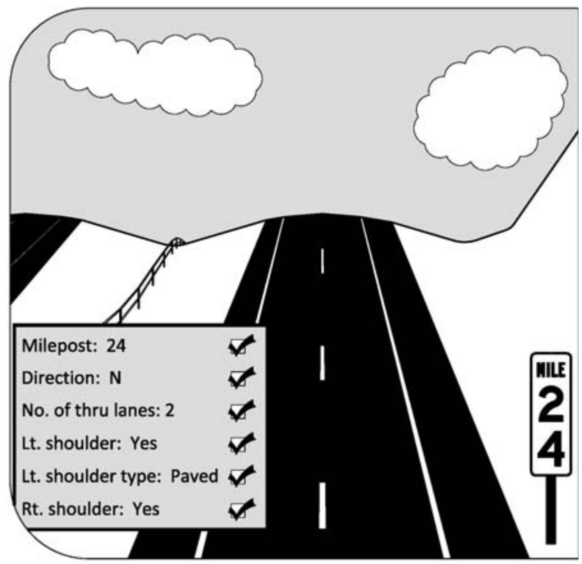
ESTABLISH PERFORMANCE GOALS

Performance goals define improvements (e.g., the reduction of missing data in critical roadway elements to less than five percent in two years) and would be the responsibility of the committee. Bearing in mind that a goal is useless unless agreed upon by the data owner, all goals should not only be clear and realistic but also cause the agency to strive to improve upon the status quo. States are encouraged to develop goals based (at least in part) on historical trends, predictive analyses, or some other analytically based method.

DEVELOP A SYSTEM OF INTERNAL QUALITY-CONTROL CHECKS

The development of a method of internal quality-control checks was discussed under the *Accuracy* section in Chapter 2, with a suggested additional measure concerning attribute values within reasonable ranges and consistency with related variables.

It was also noted under the discussion of "consistency across time" that there needs to be computer-based practices that can help detect shifts in coding across time. While one would expect the same location to change over the years due to construction modifications, one would also expect the basic attributes of an inventory file *in total* to stay somewhat consistent across years. Simple checks, such as the number of miles or junctions inventoried each year, could detect major changes in the inventory database that are likely erroneous. Year-to-year comparisons of the percentage for each attribute for a given variable (i.e., the percent within each median type, shoulder type, degree of curve category, etc.) can provide even more detailed information on possible undocumented coding changes. The FHWA's HSIS has computerized such a series of checks and annually compares the coding for each variable in the new inventory file (and all other files) to the coding in the file from the previous year. The program has a defined set of allowable changes to percentage or frequency and outputs only those variables that fail to meet these criteria. Those outputted variables are then examined in more detail by looking at the codes across multiple years. Questions are then directed back to the owner agency, and, based on their input, corrections are made where necessary. Documentation of legitimate changes is then included in the User Manual under the relevant variable. To make multiyear analyses easier, the HSIS also annually changes the codes and attributes for a given variable from all previous years to match the current year codes. (Since attributes are often added in the middle of a set of codes, such action does require significant effort.)



A second consistency-across-time issue that is much more difficult to solve is that the address of the same roadway location can change across years in linear referencing systems (e.g., route/milepost). Because most analyses are multiyear, it is often important that an analyst be able to trace the same roadway segment or intersection across multiple years even if the address has changed. (Note that this problem is essentially solved by the use of a spatial-data system whose coordinates remain constant from year to year.) While this is not a simple problem to resolve with a computerized fix, WSDOT has developed a program for their inventory system that does just this. Other States solve the problem by manually changing the crash mileposts from past years to match the current inventory milepost.

INCREASE INVENTORY DATA USE

While the previous discussion of accessibility leaves it to the discretion of an agency to determine its targeted level of data usage, a good business practice would be to become a

"Goal 2" agency—one that strives to increase data use by new clients, whether they be inside or outside the agency. When there are more users of a dataset, there is a higher probability that problems and issues with the data can be identified. Although FHWA's HSIS attempts to limit errors in the data through a series of quality control checks before the data are released each year, it is still the case that important issues and problems are discovered by the users. Some key components of increased usage may include the following:

- Providing detailed documentation of the data in some type of "User Guide."
- Marketing the data beyond the normal users.
- Meeting data request within a short timeframe.
- Obtaining feedback from the users and resolving their issues.

DEVELOP HIGH-LEVEL SUPPORT FOR "GETTING IT RIGHT"

In the opinion of this author, some of the best State inventory systems in the Nation not only have very good leaders at the working level but also have high-level support for ensuring that both the data and data systems are of superior quality. In this context, "high-level" refers to political power in the State DOT. Unfortunately, it is not easy to determine how such support can be developed. Paramount to an executive-level backing may be a thorough understanding by the administration of (1) the data system itself, (2) how the system is used, and (3) who the key customers are, as well as continual communication between the inventory leaders and the administration. Developing innovative ways to use premium roadway data in legal liability cases may also help to win high-level support.

SUMMARY

Inventory data are becoming increasingly critical as more advanced safety management tools—such as the Highway Safety Manual, the IHSDM, and SafetyAnalyst—are introduced that require these data. Future safety program decisions made by State and local agencies will be predicated upon high-quality roadway inventory data. Performance measures are tools that can be used to increase the quality of inventory data. Significant effort will be required to realize the full benefits of incorporating measures into an agency's data inventory program. Decisions will have to be made concerning what performance measures are most likely to be useful to a given user agency, the specific details of how each measure will be defined, and who will be responsible for their periodic measurement. Even if gauged regularly, measures alone will be of little use to an agency unless a corresponding problem-correction process and dedicated staff are established. Well-defined and agency-accepted performance measures can improve inventory data when combined with sound performance measure-related business practices.

REFERENCES

1. Lefler, Nancy X., F. Council, H. McGee, D. Harkey, D. Carter, M. Daul. *Model Inventory of Roadway Elements – MIRE, Version 1.0, Final Report*. Washington, D.C.: Federal Highway Administration, June 2010.

2. NHTSA. Traffic Safety *Performance Measures for States and Federal Agencies*. DOT HS 811 025. Washington, D.C.: National Highway Traffic Safety Administration, 2008.

3. Hedlund, James. *Model Performance Measures for State Traffic Record Systems White Paper: Request for Comment on Proposed Measures and Guidance*. Washington, D.C.: National Highway Traffic Safety Administration, July 2009 (Unpublished).

4. Hedlund, James. *Model Performance Measures for State Traffic Records Systems – Draft Report*. Washington, D.C.: National Highway Traffic Safety Administration, Nov. 2009.

5. NHTSA. *Model Performance Measures for State Traffic Records Systems*. DOT HS 811 441. Washington, D.C.: National Highway Traffic Safety Administration, February 2011.

6. Boodlal, L., J. Emery and R. Souleyrette. *Crash Data Improvement Program Guide*. Washington, D.C.: Federal Highway Administration, April 2010. (See http://safety.fhwa.dot.gov/cdip/finalrpt04122010/).

7. Traffic Safety Analysis Systems & Services. *Current State of Traffic Safety Information Systems Quality Metrics*. Washington, D.C.: National Highway Traffic Safety Administration, 2008 (Unpublished Draft Report).

8. Furst, Anthony. *Guidance Memorandum on Fundamental Roadway and Traffic Data Elements to Improve the Highway Safety Improvement Program*. Washington, D.C.: Federal Highway Administration, August 1, 2011. (See http://safety.fhwa.dot.gov/tools/data_tools/memohsip072911/).

9. Winter, David R. and James Cheatham. *Geospatial Network for All Public Roads (Memorandum)*. Washington, D.C.: Federal Highway Administration, August 7, 2012.

For More Information:

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