

# Real-Time Data Capture and Management Evaluation and Performance Measures

## Evaluation Framework

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16. Abstract Through connected vehicle research, the U.S. DOT Intelligent Transportation Systems Joint Program Office (ITS JPO) is leading an effort to assess the potential for systematic and dynamic data capture from vehicles, travelers and the transportation system infrastructure to enhance current operational practices and transform future surface transportation systems management. The crosscutting Real-Time Data Capture and Management (DCM) Program is the vehicle for this important effort. The purpose of the Real-Time Data Capture and Management Evaluation and Performance Measures project is twofold: 1) To identify a set of performance measures that can be used to evaluate data sets and data environments that are developed during Phase II (Research) of the DCM program; and 2) To develop an evaluation framework to quantify the benefits of the data sets and data environments developed through the program. This project will support the evaluation of quantitative and qualitative benefits from research conducted as part of Phase II the DCM Program. The measures and framework may be refined in Phase II (Research) and further tested in Phase III (Implementation) of the DCM Program. The Evaluation Framework is comprised of the following steps: Step 1. Establish the scope and timing for the evaluation. Step 2. Develop a logic model for the evaluation. Step 3. Identify evaluation questions to be answered as part of the evaluation. Step 4. Select performance measures. Step 5. Establish data collection parameters and collect data. Step 6. Calculate results for performance measures. Step 7. Set data quality targets. Step 8. Assess benefit/cost. Step 9. Summarize evaluation results. Step 10. Complete the feedback cycle.					
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# Executive Summary

Through connected vehicle research, the U.S. DOT Intelligent Transportation Systems Joint Program Office (ITS JPO) is leading an effort to assess the potential for systematic and dynamic data capture from vehicles, travelers and the transportation system infrastructure to enhance current operational practices and transform future surface transportation systems management. The crosscutting Real-Time Data Capture and Management (DCM) Program is the vehicle for this important effort.

The purpose of the Real-Time Data Capture and Management Evaluation and Performance Measures project is twofold: 1) To identify a set of performance measures that can be used to evaluate data sets and data environments that are developed during Phase II (Research) of the DCM program; and 2) To develop an evaluation framework to quantify the benefits of the data sets and data environments developed through the program. This project will support the evaluation of quantitative and qualitative benefits from research conducted as part of Phase II the DCM Program. The measures and framework may be refined in Phase II (Research) and further tested in Phase III (Implementation) of the DCM Program.

The Technical Memorandum on Performance Measures presented an initial set of performance measures for evaluating DCM Program activities. These measures were developed based on the vision, mission, objectives and strategy established for the Program. Enhancements were made to the performance measures and are presented in this report.

The Evaluation Framework is comprised of the following steps:

- Step 1. Establish the scope and timing for the evaluation.
- Step 2. Develop a logic model for the evaluation.
- Step 3. Identify evaluation questions to be answered as part of the evaluation.
- Step 4. Select performance measures.
- Step 5. Establish data collection parameters and collect data.
- Step 6. Calculate results for performance measures.
- Step 7. Set data quality targets.
- Step 8. Assess benefit/cost.
- Step 9. Summarize evaluation results.
- Step 10. Complete the feedback cycle.

Each of these steps are described in detail and specific examples are provided to demonstrate the concepts.

# Introduction

## Background

Through connected vehicle research, the U.S. DOT Intelligent Transportation Systems Joint Program Office (ITS JPO) is leading an effort to assess the potential for systematic and dynamic data capture from vehicles, travelers and the transportation system infrastructure to enhance current operational practices and transform future surface transportation systems management. The crosscutting Real-Time Data Capture and Management (DCM) Program is the vehicle for this important effort. It is designed to coordinate across connected vehicle initiatives to identify joint data needs in the areas of safety, mobility, and environment with a core philosophy to “collect once, preserve, use many times.”

## Project Scope

The purpose of the Real-Time Data Capture and Management Evaluation and Performance Measures project is twofold: 1) To identify a set of performance measures that can be used to evaluate data sets and data environments that are developed during Phase II (Research) of the DCM program; and 2) To develop an evaluation framework to quantify the benefits of the data sets and data environments developed through the program. This project will support the evaluation of quantitative and qualitative benefits from research conducted as part of Phase II (Research) the DCM Program. The measures and framework may be refined in Phase II (Research) and further tested in Phase III (Implementation) of the DCM Program.

## Organization of Report

The report is organized in the following sections:

- Section 2 – Performance Measures Framework
- Section 3 – Evaluation Framework
- Section 4 – Implementation Issues
- Section 5 – Lessons Learned

The appendices are also a critical part of the evaluation framework, and contain the following supplemental information:

- Appendix A – Mapping of Data Environment Concept to Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) Technology Test Bed
- Appendix B – Example Evaluation Framework for a Regional Data Environment
- Appendix C – Example Evaluation Framework for the DCM Program
- Appendix D – Benefit-Cost/Risk Management for Data Programs

# Chapter 1 Performance Measures Framework

The *Technical Memorandum on Performance Measures* developed in Task 2 presented initial measures to evaluate the activities of the DCM Program and the data sets and data environments that will be created as part of Phase II of the program. This section identifies enhancements to the performance measures identified since development of the *Technical Memorandum on Performance Measures*. The performance measures apply to both DCM Program activities and the capture and management of data in data environments.

## Performance Measures for the Data Capture and Management Program

The *Technical Memorandum on Performance Measures* presented an initial set of performance measures for evaluating DCM Program activities. These measures were developed based on the vision, mission, objectives and strategy established for the Program. Enhancements were made to the performance measures based on the following influences:

- The expected outcomes for the DCM program were updated as follows (based on information from the ITS Joint Program Office website, [http://www.its.dot.gov/data\\_capture/data\\_capture.htm](http://www.its.dot.gov/data_capture/data_capture.htm)):
  - Establishment of one or more multi-source data environments for the development and testing of safety, mobility, and environment applications.
  - Engagement of stakeholders to assist in defining the requirements for test data environments and to encourage active use of prototypes and test beds.
  - Identification of data management processes, operational practices, standards, integration, and rules for data exchange and sharing, particularly across jurisdictions.
  - Successful testing that validates assumptions about:
    - data (availability and accessibility of sources, quality, reliability, consistency, timing, etc.).
    - management and operational practices (how real-time data capture and use is managed).
    - benefits, as they are demonstrated through testing of the applications.
- Program Tracks for the DCM program were updated based on information from the ITS Joint Program Office website:
- Track 1: Engage stakeholders for input across all phases from foundational analysis to pilot deployment.



- Reconsider all aspects of how public sector agencies (including the federal government) procure, acquire, capture, store, manage, and share real time data. (Objective 1A)
- Ensure strong connections with other connected vehicle research activities (Objective 3C)
- Track 2: Develop data environments and address technical, institutional, and standards issues surrounding the collection and dissemination of data.
  - Determine the composition and capability of the projected high-value, end-state, data environments (Objective 2B)
  - Create multiple data environments (Objective 2C)
  - Capture and manage real time data through a data warehouse or distributed network (Objective 2D)
  - Ensure appropriate federal role in influencing and facilitating enhanced data capture and management practices (Objective 3D)
  - Proactively address technical and institutional policy barriers that are associated with the capture, management, and sharing of data (Objective 3A)
  - Implement data management standards<sup>1</sup> and processes representing best practices (Objective 3B)
- Track 3: Conduct proof-of-concept tests and test standards, procedures, tools, and protocols to produce implementation guidance for a real-world environment.
  - Design laboratory experiments and field tests to meet identified data needs in the most cost-effective way. Data in these experiments and tests will be collected in a systematically structured manner and well documented. (Objective 2A)
- Track 4: Conduct pilot deployments and demonstrate the data capture and data management techniques in an operational setting, while giving stakeholders the opportunities to develop systems beyond the life of the program.
  - Demonstrate the collection, storage and dissemination of real-time data in an operational environment (Objective 2E)
- Track 5: Develop evaluation and performance measures.
  - Evaluate program to ensure goals and objectives are met (Objective 3F)
- Track 6: Coordinate outreach and technology transfer. Test data sets, data collection, and analysis methodologies will be shared with stakeholders.
  - Ensure broad collaboration surrounding data environment utilization (Objective 3E)
- Some clarification or changes were made as a result of interviews with internal U.S. DOT stakeholders conducted as part of this project.
- Further refinements were made based on the development of the Evaluation Framework described in Section 3 of this report.

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<sup>1</sup> Data Management Standards are defined to include metadata, data dictionaries, and reference model for the purposes of this report

Table 1 recommends performance measures for the specific program tracks within the DCM Program. The table refers to “Data Capture and Management Research Data Exchange” hereinafter called Research Data Exchange.

**Table 1. Performance Measure Framework for the DCM Program**

Program Track	Associated Program Goals and Objectives	Performance Indicators
<b>Track 1: Stakeholder Engagement</b>	Reconsider all aspects of how public sector agencies (including the federal government) procure, acquire, capture, store, manage, and share real time data. (Objective 1A) Ensure strong connections with other connected vehicle research activities (Objective 3C)	Data Business Plan completed Active engagement of internal and external stakeholders and researchers in data standards development processes Agency statement on open data/open government for citizen engagement
<b>Track 2: Develop Data Environments and Address Technical, Institutional and Standards Issues</b>	Determine the composition and capability of the projected high-value, end-state, data environments (Objective 2B) Create multiple data environments (Objective 2C) Capture and manage real time data through a data warehouse or distributed network (Objective 2D) Ensure appropriate federal role in influencing and facilitating enhanced data capture and management practices (Objective 3D) Proactively address technical and institutional policy barriers that are associated with the capture, management, and sharing of data (Objective 3A)	Data application mapping completed Data environments created Research Data Exchange developed to support access to data environment Data Managers assigned and tasked with connecting, fostering and managing system of data environments Access and security protocols developed Guidelines for hosting, aggregation, and intellectual property rights developed Data Privacy protocols developed Long term data governance and stewardship rules developed Data storage and backup requirements defined and met Protocols are in place to address potential system failure consequences

Program Track	Associated Program Goals and Objectives	Performance Indicators
	Implement data management standards <sup>2</sup> and processes representing best practices (Objective 3B)	Guidelines for data collection protocols developed based on national/international standard message sets and interfaces Guidelines for collection, storage and dissemination of real-time data developed Guidelines for quality assurance (data quality flagging) of data sets/environments clearly defined and documented Metadata and data dictionary standards developed Data documentation guidelines developed Reference Model <sup>3</sup> developed
<b>Track 3: Conduct Proof-of-Concept Tests</b>	Design laboratory experiments and field tests to meet identified data needs in the most cost-effective way. Data in these experiments and tests will be collected in a systematically structured manner and well documented. (Objective 2A)	Laboratory experiments and field tests designed to assemble and test data sets featuring multi-source data collected using emerging technology Data management standards, guidelines, and protocols validated Data fusion techniques developed
<b>Track 4: Conduct Pilot Deployments</b>	Demonstrate the collection, storage and dissemination of real-time data in an operational environment (Objective 2E)	Designated support staff in place for continued operations and maintenance of Data Capture and Management Research Data Exchange Data forums for users to report anomalies, inconsistencies, potential errors, and project successes developed Frequently Asked Questions (FAQs), Glossary, and Contacts pages developed Multi-state and regional demonstrations of mobility applications conducted

<sup>2</sup> Includes metadata, data dictionaries, and reference model

<sup>3</sup> The FHWA ITS Standards Technical Assistance Program is currently developing a Reference Model, which will establish standard data conformity requirements for data received from state and local agencies, vehicle manufacturers, and the private sector.

Program Track	Associated Program Goals and Objectives	Performance Indicators
<b>Track 5: Develop Evaluation and Performance Measures</b>	Evaluate program to ensure goals and objectives are met (Objective 3F)	Evaluation and performance measure framework developed Survey mechanism for user feedback developed and implemented Ongoing assessment of user satisfaction conducted Ongoing assessment of DCM Program activities conducted Ongoing assessment of data sets and data environments conducted
<b>Track 6: Coordinate Outreach and Technology Transfer</b>	Ensure broad collaboration surrounding data environment utilization (Objective 3E)	Synthesis of foundational research developed Development of outreach materials such as reports, briefing documents, training and education materials, and best practice toolboxes Capacity building activities such as technical assistance, workshops, conferences, training, and education

# Performance Measures for the Capture of Data from Data Sets and Data Environments

The measures defined in this section will be used to guide the development of and assess the value of data environments and associated data sets. The *Data Capture and Management Program Vision: Objectives, Core Concepts and Projected Outcomes* report<sup>4</sup> and *Data Capture and Management Research Data Exchange Concept of Operations* (currently in development<sup>5</sup>) established the following definitions:

A **data set** is defined as a collection of related data, organized into a regular and consistent format. A data set could consist of observed data, or a combination of observed, derived, and/or simulated data from a broad spectrum of data sources (travelers, vehicles, infrastructure, or simulation). Data sets are documented with metadata, and are made broadly available to researchers and application developers under open data licenses.

A **data environment** is defined as:

- A well-organized collection of data of specific type and quality,
- Captured and stored at regular intervals from one or more sources,
- Systematically shared in support of one or more applications, and
- Designed to promote research, implementation and decision making.

A data environment can be thought of as the *logical* collection of data compiled and organized to support research and decision making, regardless of where data elements originate and are stored. A single data environment may include one or more data sets that physically reside in different data management systems. A **data management system** is the *physical* system that stores archived data (data sets), real-time data feeds, and/or data environments. The Data Capture and Management Research Data Exchange (hereinafter called Research Data Exchange) physically consists of interconnected Data Management Systems and the Data Portal, which is a web-based interface for users to access the Research Data Exchange.

The differences between data sets and data environments is further explained in Appendix A. Appendix A contains diagrams mapping these concepts to the prototype data sets and data environment (Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) Technology Test Bed.)

The *Technical Memorandum on Performance Measures* presented an initial set of performance measures for evaluating data sets and data environments in each of the following categories:

- **Output Performance Measures.** Output measures quantify the output of the DCM Program. These measures relate to the physical quantities of items, levels

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<sup>4</sup> “Data Capture and Management Program Vision: Objectives, Core Concepts and Projected Outcomes,” United States Department of Transportation, Washington, DC, April 2010.

<sup>5</sup> Noblis, “Concept of Operations: Data Capture and Management Research Data Exchange,” Prepared for the United States Department of Transportation, March 29, 2011.

of effort expended, scale or scope of activities, or the efficiency in converting resources into some kind of product or service.

- **Outcome Performance Measures.** Outcome measures quantify the benefits of the DCM Program from the perspective of the user. These measures relate to how well the program is meeting its mission and stated goals.
- **Quality Performance Measures.** Measures related to the accessibility, timeliness (latency), completeness, validity and coverage of data sets and data environments. These measures need to be closely aligned with stakeholder needs.

The following enhancements were made to the initial set of performance measures:

- The Research Data Exchange was added as a category under applicability.
- Delineation of research vs. operations phases was added as an additional method for categorizing performance measure applicability. Research is considered to be the first part of the phase and operations picks up where the research leaves off (after 2014). The distinction is made because some measures (i.e. Number of demonstrations conducted) are more relevant to research as opposed to actual deployment of the data environments (in an operational sense). Many of the measures refer to the Research Data Exchange and to the Operations environment. The Research Data Exchange only applies during the research program (until 2014). After 2014, the measures would be used to measure data sets and environments in an operational sense.
- The measures were re-organized to better describe the outputs and outcomes as defined in the evaluation framework in Section 3.
- For the quality measures, the data life cycle stages were redefined to better match that of the data environment concept: data capture, data processing, and data storage/sharing.
- Some clarification or changes were made as a result of interviews with internal U.S. DOT stakeholders conducted as part of this project.
- Additional performance measures were identified following development of the Evaluation Framework described in Section 3 of this report.
- Performance measures related to the number of registered users and projects on the Research Data Exchange were removed based on conceptual changes to the Research Data Exchange Concept of Operations (draft report – March 29, 2011). An additional measure was added for the number of projects discussed in user forums on the Research Data Exchange.

Table 2 shows the output measures. It includes the measures, definition of measure, data requirements, applicability (data sets, data environment, and/or Research Data Exchange), influencing/exogenous factors and potential data source for measure.

Table 3 shows the same information for outcome measures.

Table 4 lists quality measures and indicates the measure, definition, data requirements, stage to which the measure relates (data capture, data processing, and data storage/sharing), applicability (data sets and/or data environment), influencing/ exogenous factors and potential data source.

Each measure is prioritized as low, medium or high based on their importance to the DCM Program. At this stage, all of the measures are applicable to all modes (light vehicles, transit or freight).



**Table 2. Output Performance Measures**

Performance Measure	Definition	Priority	Data Requirements	Applicability			Phase		Influencing/ Exogenous Factors	Potential Data Source
				Data Sets	Data Environments	Research Data Exchange	Research	Operations		
1. Percent of data sets/ environments used for field testing	Self explanatory	M	Number of field tests performed Number of data sets/data environments utilized	●	●		●		Suitability for testing	Count of data sets/ environments
2. Availability of support staff in place for the Research phase of Research Data Exchange	Self explanatory	H	Coverage during hours of operations			●	●		Continued funding and resources to maintain and administer the system	Real-Time Data Capture and Management Program
3. Availability of support staff in place for the Operations phase of Research Data Exchange	Self explanatory	H	Coverage during hours of operations	●	●			●	Continued funding and resources to maintain and administer the system	Real-Time Data Capture and Management Program
4. Number of projects discussed in user forums on the Research Data Exchange	Self explanatory	H	Number of projects discussed in forums on the Research Data Exchange			●	●		Success of stakeholder outreach process	Monitoring of user forums

Performance Measure	Definition	Priority	Data Requirements	Applicability			Phase		Influencing/ Exogenous Factors	Potential Data Source
				Data Sets	Data Environments	Research Data Exchange	Research	Operations		
5. Number of participants collaborating in user forums on the Research Data Exchange	Self explanatory	M	Number of participants discussing issues in forums on the Research Data Exchange			●			Success of stakeholder outreach process	Monitoring of user forums
6. Number of demonstrations conducted	Self explanatory	H	Number of multi-state or regional demonstrations included in Pilot Deployment phase				●		Success of stakeholder outreach process, stakeholder willingness to participate	Real-Time Data Capture and Management Program
7. Number of user surveys conducted	Self explanatory	M	Number of user surveys conducted for the Research Data Exchange			●	●		Success of stakeholder outreach process, stakeholder willingness to participate	Web server statistics
8. Change in number of outreach activities conducted	Self explanatory	M	Number of outreach activities such as technical assistance, workshops, conferences, training, and education				●	●	Success of stakeholder outreach process	Real-Time Data Capture and Management Program

Performance Measure	Definition	Priority	Data Requirements	Applicability			Phase		Influencing/ Exogenous Factors	Potential Data Source
				Data Sets	Data Environments	Research Data Exchange	Research	Operations		
9. Protocols are in place to address potential system failure consequences	Self explanatory	H	Presence and operation of system failure detection and ability to address issues		●	●	●	●	None	Real-Time Data Capture and Management Program

**Table 3. Outcome Performance Measures**

Performance Measure	Definition	Priority	Data Requirements	Applicability			Phase		Influencing/ Exogenous Factors	Potential Data Source
				Data Sets	Data Environments	Data Exchange	Research	Operations		
1. User satisfaction with the Research phase of the Research Data Exchange	A measure of perception of users of the data exchange functionality	H	User opinions on adequacy and usefulness of data exchange function (from a research standpoint)			●	●		Desired use of data environment, ability to understand, gauge and track stakeholder satisfaction	Stakeholder feedback mechanism

Performance Measure	Definition	Priority	Data Requirements	Applicability			Phase		Influencing/ Exogenous Factors	Potential Data Source
				Data Sets	Data Environments	Data Exchange	Research	Operations		
2. User satisfaction with Operations phase of the Research Data Exchange	A measure of perception of users of the data exchange functionality	H	User opinions on adequacy and usefulness of data exchange function (from an operations standpoint)	●	●			●	Desired use of data environment, ability to understand, gauge and track stakeholder satisfaction	Stakeholder feedback mechanism
3. User satisfaction with the data content in the Research phase of the Research Data Exchange	A measure of perception of users of the data exchange content, which could include data sets, metadata, and web-based resources	H	User opinions on adequacy and usefulness of data exchange content	●	●	●	●		Desired use of data environment, ability to understand, gauge and track stakeholder satisfaction	Stakeholder feedback mechanism
4. User satisfaction with the data content in the Operations phase of the Research Data Exchange	A measure of perception of users of the data exchange content, which could include data sets, metadata, and web-based resources	H	User opinions on adequacy and usefulness of data exchange content	●	●	●		●	Desired use of data environment, ability to understand, gauge and track stakeholder satisfaction	Stakeholder feedback mechanism

Performance Measure	Definition	Priority	Data Requirements	Applicability			Phase		Influencing/ Exogenous Factors	Potential Data Source
				Data Sets	Data Environments	Data Exchange	Research	Operations		
5. Ability of data sets/ data environments to be shared and integrated with other data sources	A measure of how data set can be shared with a broad set of stakeholders and integrated with other data sources	H	User opinions on ability of data to be shared/integrated with other data sources	●	●		●	●	Extent of standardization, metadata and common definitions	Data environment documentation and stakeholder feedback
6. Change in number of downloads (transfer of data) of data sets	Self explanatory	H	Number of times data sets are downloaded by users	●			●	●	Ability to track what data sets are being used for (e.g., many downloads may occur for one application)	Web server statistics
7. Change in number of users accessing identical (consistent) data sets	A measure of the data sets that have been used multiple times	H	Number of users accessing identical (consistent) data sets Total number of data sets	●			●	●	Ability to track what data sets are being used for (e.g., many downloads may occur for one application)	Web server statistics
8. Change in number of contributors providing/sharing data sets	A measure of the number of contributors providing/sharing data on the data exchange	M	Number of unique contributors	●			●	●	Ability to track data sets being contributed/ shared	Web server statistics

Performance Measure	Definition	Priority	Data Requirements	Applicability			Phase		Influencing/ Exogenous Factors	Potential Data Source
				Data Sets	Data Environments	Data Exchange	Research	Operations		
9. Percent of data sets that are real-time	Self explanatory	M	Definition of real-time and number of data sets in each category	●			●	●	Uses of data	Metadata
10. Percent of data sets that meet open source format requirements	Data and data processing tools should be submitted in a form that does not require purchase of proprietary software for use and places no monetary or licensing restrictions	H	Number of data sets that meet open source format requirements Total number of data sets	●			●	●	Some agencies may not be permitted to participate in Open Source	Count of data sets/ environments
11. Percent of data sets that have been verified for quality and accuracy	Self explanatory	M	Number of data sets/ environments that meet data quality standards Total number of data sets/ environments	●			●	●	Cost and ability of data owners to validate data sets	Data owner feedback or website documentation requirements

Performance Measure	Definition	Priority	Data Requirements	Applicability			Phase		Influencing/ Exogenous Factors	Potential Data Source
				Data Sets	Data Environments	Data Exchange	Research	Operations		
12. Flexibility of data set/data environment to respond to changes in innovation	Data set/environment is scalable in terms of deployment ability in a variety of technical platforms	H		●	●		●	●	Change in technology	
13. Number of prototype data environments developed	Self explanatory – may include those developed by the Program and other private sources	M	Number of prototype data environments developed		●		●		Financial constraints, data environments developed external from Real-Time Data Capture and Management program	Real-Time Data Capture and Management Program
14. Value of Metadata (description of the data) for data sets, environments and Data Exchange	Presence and quality of metadata	M	Presence of metadata and usefulness to users	●	●	●	●	●	Quality of metadata entered	Metadata presence and stakeholder feedback

Performance Measure	Definition	Priority	Data Requirements	Applicability			Phase		Influencing/ Exogenous Factors	Potential Data Source
				Data Sets	Data Environments	Data Exchange	Research	Operations		
15. Percent of data environments that permit re-use by stakeholders	A measure of the data environments that have been used multiple times	H	Number of users accessing identical (consistent) data sets Total number of data sets/ environments		●		●	●	Agreements with data providers	Web server statistics
16. Percent of data sets/ environments utilized for applications	Self explanatory	H	Number of data sets/ environments that are being utilized to support at least one application Total number of data sets/ environments	●	●		●	●	Will need stakeholder communication. Data may be downloaded but not used	Stakeholder feedback mechanism



Performance Measure	Definition	Priority	Data Requirements	Applicability			Phase		Influencing/ Exogenous Factors	Potential Data Source
				Data Sets	Data Environments	Data Exchange	Research	Operations		
17. Percent of data sets/ environments that support multiple applications	A measure of the increase in percent of data sets/ environments that are being utilized to support more than one application (in the areas of mobility, safety, environment, or other)	M	Number of data sets/ environments that are being utilized to support more than one application Total number of data sets/ environments	●	●		●	●	Will need stakeholder feedback on actual use of data in applications	Stakeholder feedback mechanism
18. Percent of data sets/environment s that support multi-modal or cross-modal applications	A measure of the increase in percent of data sets/ environments that are being utilized to support multi-modal or cross-modal applications	M	Number of data sets/ environments that are being utilized to support multi-modal/ cross-modal application Total number of data sets/ environments	●	●		●	●	Will need stakeholder feedback on actual use of data in applications	Stakeholder feedback mechanism
19. Number of distinct applications developed using the data environment	A measure of utilization of data environments for application development	H	Number of applications developed based on data environments		●		●	●	Ability of data to meet stakeholder needs, availability of other non Program data sets	Stakeholder feedback mechanism

Performance Measure	Definition	Priority	Data Requirements	Applicability			Phase		Influencing/ Exogenous Factors	Potential Data Source
				Data Sets	Data Environments	Data Exchange	Research	Operations		
20. Number of multi-modal / cross-modal applications developed using the data environment	A measure of utilization of data environments for multi-modal or cross-modal application development	H	Number of multi-modal or cross-modal applications developed based on data environments		●		●	●	Ability of data to meet stakeholder needs, availability of other non Program data sets	Stakeholder feedback mechanism
21. Number of real-time applications used by the data environment	A measure of utilization of data environments for real-time application development	H	Number of real-time applications developed based on data environments		●		●	●	Ability of data to meet stakeholder needs, availability of other non Program data sets	Stakeholder feedback mechanism
22. Number of applications that utilize other non-Program data environments	A measure of how stakeholders are going elsewhere for data	H	Data sources for applications		●		●	●	Availability, quality or other data sources	Stakeholder Feedback Mechanism
23. Number of technical papers developed that utilize the data environment	A measure of utilization of data sets/ environments for technical papers	L	User posts within the Research Data Exchange on references to published materials		●		●		Ease of availability of information	Website references and stakeholder feedback

Performance Measure	Definition	Priority	Data Requirements	Applicability			Phase		Influencing/ Exogenous Factors	Potential Data Source
				Data Sets	Data Environments	Data Exchange	Research	Operations		
24. Cost savings from the elimination of redundant data collection and management efforts	A measure of the cost savings from the elimination of redundant data collection and management efforts	H	Estimate of the number of redundant data collection and management efforts eliminated Cost of these elements		●		●	●	Cost of collection, use of existing data and new data environments, ability to quantify benefits and risks	Benefit/Cost calculations and risk assessment processes
25. Cost effectiveness of maintaining data environments	A measure of the costs, staff and resources required to maintain data environments	M	Estimate of the resources required to maintain data environments and the data exchange Cost of these elements		●		●	●	Cost of updating data environments and maintaining the data exchange, ability to quantify benefits and risks	Benefit/Cost calculations and risk assessment processes
26. Collaboration among users of data sets, environments and Data Exchange	A measure of the degree of collaboration among data users	M	On-line conversation among data users	●	●	●	●	●	Ability of websites to track data	Web server statistics

**Table 4. Data Quality Performance Measures**

Performance Measure	Definition	Priority	Data Requirements	Stage of Data Lifecycle			Applicability		Influencing/ Exogenous Factors	Potential Data Source
				Data Capture	Data Processing	Data Storage/ Sharing	Data Sets	Data Environments		
1. Accuracy - Percent of data values that are correct when compared to a source assumed correct.	The degree of agreement between a data value or set of values and a source assumed to be correct	H	Data values – number correct and not correct, assumption of correct, stakeholder feedback regarding required accuracy level	●	●		●		Accuracy requires continuous monitoring and calibration. Absence of ground truth data is an issue. Processes for smoothing data can also affect accuracy	Data set documentation and metadata, stakeholder feedback mechanism
2. Accessibility	The relative ease with which data can be retrieved and manipulated by data consumers to meet their needs	H	Ability of data to be accessed and downloaded			●		●	Stakeholder access to website and technical proficiency in downloading	Website characteristics and stakeholder feedback mechanism
3. Validity - Percent of data values that pass/fail data validity criteria.	The degree to which data values satisfy acceptance requirements of the validation criteria or fall within the respective domain of acceptable values	H	Validation criteria as required by stakeholders and application needs		●		●		Reasonableness of validity standards and stakeholder expectations	Data set documentation and metadata, stakeholder feedback mechanism

Performance Measure	Definition	Priority	Data Requirements	Stage of Data Lifecycle			Applicability		Influencing/ Exogenous Factors	Potential Data Source
				Data Capture	Data Processing	Data Storage/ Sharing	Data Sets	Data Environments		
4. Timeliness (Latency) – Percent of data available within a specified threshold time frame (e.g., days, hours, minutes)	The degree to which data values or a set of values are provided within the time frame required or specified	M	Time between data occurrence, collection and delivery	●	●			●	Definitions of real time, needs of stakeholders, availability of data to be delivered	Data set documentation and metadata, stakeholder feedback mechanism
5. Completeness – Percent of data fields having values entered into them	The degree to which data values are present in the attributes that require them	M	Number of data fields – total and populated	●	●			●	Usefulness of the measure is subject to data set being measured. The measure assumes all data fields to be equally important	Data set documentation and metadata, stakeholder feedback mechanism
6. Spatial Completeness	The degree to which data values are available for all network components required to support applications – freeways, ramps, arterials, local streets, etc.	M	Data coverage needed by stakeholders and provided by data environment	●	●			●	Needs of stakeholders, availability of data to be delivered for required network components	Data set documentation and metadata, stakeholder feedback mechanism

Performance Measure	Definition	Priority	Data Requirements	Stage of Data Lifecycle			Applicability		Influencing/ Exogenous Factors	Potential Data Source
				Data Capture	Data Processing	Data Storage/ Sharing	Data Sets	Data Environments		
7. Temporal completeness	The degree to which data are available for all time periods required to support applications	M	Data coverage needed by stakeholders and provided by data environment	●	●			●	Needs of stakeholders, availability of data to be delivered for all time periods	Data set documentation and metadata, stakeholder feedback mechanism
8. Modal completeness	The degree to which data are available for all modes of transportation required to support applications	M	Modal coverage needed by stakeholders and provided by data environment	●	●			●	Needs of stakeholders, availability of data to be delivered from various modes	Data set documentation and metadata, stakeholder feedback mechanism
9. Coverage – Percent of network for which data is available	The degree to which data values accurately represent the whole of that which is to be measured	L	Data coverage needed by stakeholders and provided by data environment		●		●		Total population and sample for data	Data set documentation and metadata, stakeholder feedback mechanism

# Chapter 2 Evaluation Framework

This section describes a general evaluation framework that can be used to assess the activities of the DCM Program, as well as the effectiveness of data sets and data environments developed through the program. The framework utilizes basic principles of program evaluation, logic models, and performance-based measurement. It is designed to be adaptable and scalable to accommodate many different evaluation contexts.

## Evaluation Framework

The evaluation framework is structured as a sequence of steps as follows:

- Step 1. Establish the scope and timing for the evaluation.** The framework can be scaled to accommodate any type of evaluation. For example, the evaluation framework could be used to assess the overall DCM Program, quantify the accomplishments of individual program tracks, or it could be used to evaluate the effectiveness of data sets or data environments developed through the program. Evaluations should be conducted at critical decisions points within the DCM Program when feedback is required to demonstrate progress, capture significant achievements, or influence critical program modifications or decisions. Table 5 summarizes options for evaluation timing.

**Table 5. Evaluation Timing and Design**

Timing of Evaluation	Evaluation design
<b>AFTER ONLY</b> (post program)	Evaluation is done after the program is completed. Common design, but the least reliable because we do not know what things looked like before the program.
<b>RETROSPECTIVE</b> (post program)	Participants are asked to recall or reflect on their situation, knowledge, or behavior prior to the program. It is commonly used in education and outreach program evaluations, but is dependent on stakeholder feedback.
<b>BEFORE-AFTER</b> (before and after program)	A program or aspect of a program is evaluated before the program, and then again after the program. Differences in the before/after scenarios could be attributed to the program, but many other things can happen over the course of a program that impact observed changes.
<b>DURING</b> (additional data during the program)	Collecting information at multiple times during the course of a program is a way to identify the association between program activities and outcomes. Data can be collected on program activities and services, as well as on participant progress. This evaluation could require more time and resources for data collection.

Timing of Evaluation	Evaluation design
<b>TIME SERIES</b> (multiple points before and after the program)	Time series involve a series of measurements at intervals before the program begins and after it ends. It strengthens the simple before-after design by documenting pre- and post patterns and stability of change. Ensure that other external factors do not coincide with the program and influence the observed change.
<b>CASE STUDY</b>	A case study design uses multiple sources of information and multiple methods to provide an in-depth and comprehensive understanding of the program. Its strength lies in its comprehensiveness and exploration of reasons for observed effects.

Source: Enhancing Program Performance with Logic Models, University of Wisconsin-Extension, February 2003.

- **Step 2. Develop a logic model for the evaluation.** A logic model should be developed and scaled to the scope of the evaluation. Logic models describe the linkages between program resources, program activities, and expected short-, medium- and long-term outcomes related to a specific situation, as shown in Figure 1. They communicate underlying assumptions about which program activities are required to bring out specific results or outcomes. Logic models are developed by asking the following questions in sequence<sup>6</sup>:
  - What is the current situation that the program or program component is intended to impact?
  - What will it look like when the desired situation or outcome is achieved (medium- and long-term outcomes)?
  - What knowledge or skills do stakeholders need before the desired situation or outcome is achieved (short-term outcomes)?
  - What program activities (outputs) are needed to provide stakeholders with these knowledge and skills?
  - What resources (inputs) are required to perform these activities?

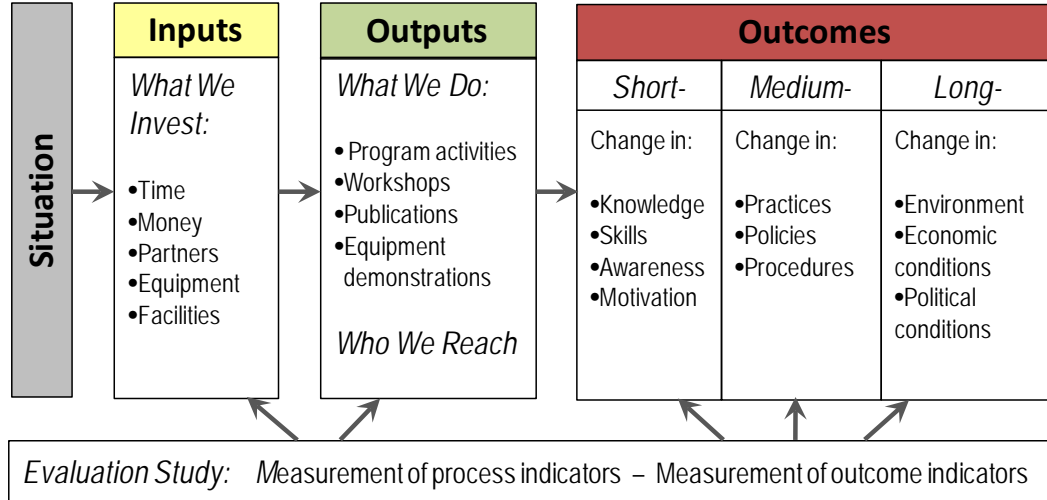
Example logic models for a regional data environment and the overall DCM Program are provided in Appendices B and C, respectively. The logic model serves as a high-level roadmap for the evaluation, and will be used as a tool for conducting the remainder of the steps in the evaluation framework.

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<sup>6</sup> Source: McCawley, Paul F. The Logic Model for Program Planning and Evaluation. University of Idaho Extension, <http://www.uiweb.uidaho.edu/extension/LogicModel.pdf>, accessed February 2011.



**Figure 1. Logic Model Template**



Source: McCawley, Paul F. The Logic Model for Program Planning and Evaluation. University of Idaho Extension, <http://www.uiweb.uidaho.edu/extension/LogicModel.pdf>, accessed February 2011.

- **Step 3. Identify evaluation questions to be answered as part of the evaluation.** The evaluation questions will depend on the context of the evaluation and the needs of the intended audience for which the evaluation is being conducted. In evaluating the DCM Program, decision makers might be interested in questions such as, *Is the DCM Program achieving its goals? Who is the program serving? Is it worth the cost?* In evaluating a data environment, DCM Program staff might be interested in questions such as, *How is a data environment performing and what is its impact on applications used by the environment? Is the data environment successfully supporting the targeted applications? Is data being collected in a coordinated, open source format across multiple applications? Is data being integrated across connected vehicles, travelers, and infrastructure? How well is data being collected, assembled and distributed?*

Table 6 lists potential audiences for the evaluation, potential questions of interest, and how the evaluation results might be used in decision making. Example evaluation questions for a regional data environment and the overall DCM Program are provided in Appendices B and C, respectively.

**Table 6. Potential Evaluation Questions**

Who will use the evaluation results?	What do they want to know from the evaluation?	How will the evaluation results be used?
DCM Program Staff	To what extent is the DCM Program reaching targeted stakeholders? To what extent and in what way is the program making a difference?	To report to the legislature To report to funding providers To change the strategy if it is not working
Participants in the connected vehicle program	How are participants benefiting? How are individual participants doing compared to others?	To decide about continued participation To share with others/tell others about the program
Decision makers	Is the DCM program achieving its goals? Who are the program partners and stakeholders? Who is the program serving? Is the program worth the cost?	To decide about support To inform policy decision making and receive knowledge about what works and what doesn't work To determine funding allocation decisions To inform future funding efforts
Stakeholder developers	What items can be transitioned to state of the practice?	To educate stakeholders on practices ready for implementation To guide agencies towards citizen engagement that can become part of agency operations
Partners in the connected vehicle program (internal/external)	How are partners benefiting? Are all partners carrying out their role?	To decide if and how to continue the partnership

- Step 4. Select performance measures.** For the evaluation of data sets and data environments, identify key characteristics such as data source/type of data (traveler, vehicle, infrastructure, or simulation), type of data environment/geographic scope (regional, corridor, freeway, or arterials), and supported modes (mode-specific, multi-modal, cross-modal). Next, identify performance measures required to answer the evaluation questions. Performance measures should be meaningful and relevant for the program or component being evaluated, as well as the desired outputs and outcomes of the evaluation framework. Potential measures can be drawn from the performance measure framework presented in Tables 1 through 4 of this report. For example, for an evaluation in the research phase of the program, performance measures that are applicable to research would be selected. Similarly, performance measures could be selected for their applicability for evaluation of a data set, a data environment, a data management system, or the Research Data Exchange. Additional measures *can* and *should be* identified as needed to adequately address the evaluation objectives, reflecting the scope of what is being evaluated. For example, evaluation at a program-wide level would involve

calculation of output and outcome measures across multiple data sets and data environments, while evaluation of a particular data environment would be limited to only the data sets contained within that data environment.

- **Step 5. Establish data collection parameters and collect data.** Tables 1 through 4 identify the data requirements, potential data sources, and survey mechanisms required to support calculation of the output and outcome performance measures. It is recommended that data collection practices (e.g., measurement practices, development of survey mechanisms, sampling design, etc.) be designed and incorporated into DCM Program track activities.
- **Step 6. Calculate results for performance measures.** The performance measures should be calculated for each of the desired outputs and outcomes. As in Step 4, calculation of performance measures should reflect the scope of what is being evaluated (e.g., program-level, across all data sets/data environments, or within an individual data environment).
- **Step 7. Set data quality targets.** Data quality targets should be established for each measure of data quality. This is done after collecting data and calculating performance measures because results should be reviewed and analyzed prior to setting targets. Targets will differ based on the type of application and key characteristics such as type of data/data source (traveler, vehicle, infrastructure, or simulation), type of data environment/geographic scope (regional, corridor, freeway, or arterials), and supported modes (mode-specific, multi-modal, cross-modal). Establishment of data quality targets should build on past research such as FHWA's 2004 report on Traffic Data Quality Measurement<sup>7</sup>, as well as the Reference Model being developed for the DCM Program as an indicator of a highly qualified data environment. It is assumed that assessment of data quality will be conducted by contributors as part of a well qualified data sets; however, it is recommended that quality assurance reviews be conducted to ensure protocols for quality adherence are being followed and to recommend corrections as needed.
- **Step 8. Assess benefit/cost.** Determination of the benefits of data programs relative to their cost is a challenging exercise. While tools and methodologies exist for determining the benefit/cost ratio of projects to use in transportation project selection and evaluation, the same is not true for data programs. However, data programs are becoming increasingly important to transportation agencies and they are responding by developing methods to value their data. For example, many states are establishing Data Business Plans that include value assessments of data sets and programs. Quantifying the cost of data programs and data sets is fairly straightforward. The benefits (or perceived benefits) of data are more challenging to determine. States are using risk management approaches to determine the perceived value of data. This is discussed further in Appendix D.  
  
**Step 8a. Determine costs.** Determine cost to provide data set, environment or program. This must include set up costs, hardware and software as well as life cycle costs associated with updating and maintaining the data.

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<sup>7</sup> Traffic Data Quality Measurement: Final Report. FHWA Report 14058, September 2004, [http://ntl.bts.gov/lib/jpodocs/reports/te/14058\\_files/index.htm](http://ntl.bts.gov/lib/jpodocs/reports/te/14058_files/index.htm), accessed February 2011.

**Step 8b. Determine benefits.** Determine the benefit or value of the data. It is not practical to quantify this in financial terms, rather, it should be expressed in terms of the impacts of not having the data. This includes evaluating the absence of the data altogether as well as the impacts of various levels of the quality of the data. For example, is the data set still useful and valid if it is 2 days old or not at the specified accuracy level. In the context of the DCM Program, the steps for identifying and assessing risks include the following:

**Identify Risks.** Risks include the impact of not having the data set/environment or having the data but at varying levels of quality (timeliness, accuracy, completeness, availability, validity, timeliness coverage).

**Assess/analyze the risks associated with data systems.** This step involves determining the relative frequency and severity of any potential risk and ranking those risks in a priority order. A risk matrix similar to the ones described in Appendix D could be used.

- **Step 9. Summarize evaluation results.** Evaluation results should be summarized in a format suitable to the scope and intended audience. If a formal report is required, report contents should include an executive summary, purpose and scope of the evaluation, explanation of evaluation goals, methods, and analysis procedures, performance measure results, and relevant conclusions and recommendations.
- **Step 10. Complete the feedback cycle.** Evaluation results should be used to demonstrate progress, communicate significant program achievements, or influence critical program modifications or decisions. The feedback cycle supports the mechanism of how data from the evaluation is accumulated and fed back to the DCM Program.

Example evaluation frameworks for a regional data environment and the overall DCM Program are provided in Appendices B and C, respectively. The benefit-cost/risk management background and research is provided in Appendix D.

# Chapter 3 Implementation Issues

This section identifies issues to be addressed in the use and implementation of the evaluation framework presented in this report. ~~The update of the evaluation framework will document issues faced during the prototype implementation period.~~

## High Level Issues

Issues to be addressed in the evaluation framework presented in this report, include the maintenance of existing data environments, establishing performance measures for future data sets and data environments, and other technical and non-technical issues. The evaluation framework will use the performance measures to evaluate the data environments and data sets. Consideration will be given to a benefit/cost analysis of the data environments.

The technical and non-technical (institutional) issues associated with the development and/or application of performance measures for the data environments and data sets include the following:

- I. Risks in the development of the data environment:
  - Specific data translation issues (e.g., the ability to convert spot speeds to link speeds and to clearly define traffic management segments).
  - Addressing location referencing of data given the large number of disparate geospatial base maps available across the country.
  - The use of open data standards (*Real-Time Data Capture and Management: Core Open Data Concepts and Preliminary Rules of Engagement (Ver. 1, March 31, 10)*) has been indicated as a desire. The institutional issues associated with this will need to be identified and considered.
  - Data quality/validity criteria will need to be developed for each data source/type of data. Screening tests for these criteria will need to be developed for real-time data feeds. Policy is needed to determine who is responsible for assessing data quality.
  - Many of the performance measures assume the existence of archived data for purposed of reporting – if the data is not archived, there is a risk to the success of the operation of the data environments.
  
- II. Risks in the application of performance measures:
  - The performance measures and evaluation framework presented in this report are intended for the test/research stage of the DCM Program (5 years). However, the measures and framework may be completely different for the

longer term, i.e., when connected vehicle applications are operational and no longer in the research phase.

- In order for the measures to be effective, they must be collected over time. Operations and maintenance may be cost prohibitive.
- Quantifying the benefits of data is challenging. Issues such as risk management and the risk of not having the data must be considered.
- Another success factor is to keep the process simple – this will be a challenge as well.
- Controlling, containing or at least explaining all the exogenous factors affecting the measures.
- Integrating with the stakeholder process underway for the connected vehicle program.
- The data source for many of the measures is a stakeholder feedback mechanism. Establishing and funding this mechanism will be a critical part of the evaluation framework.
- The business side/private sector aspect of selling data and the sustainability of business model will need to be addressed. Performance measures will need to be developed for this area.
- ~~The performance measure and evaluation framework should be field tested and refined. Testing opportunities include the Reference Model, the Clarus initiative, the Safety pilot project, test data sets, or the high priority mobility applications that have been identified.~~

## Trial Implementation Issues

It is recommended that the evaluation framework be field tested and refined as needed through a trial implementation. Field testing should take place once there are more DCM Program activities available to evaluate. Testing opportunities include the following:

- Initial test data sets are due to U.S. DOT by the end of December 2011. Testing using the evaluation framework could take place as early as January 2012.
- The Research Data Exchange will be operational in spring 2012. The evaluation framework could be used to identify performance measures for the Research Data Exchange.
- There is an opportunity to test the evaluation framework out on the prototype dataset. Usage statistics and other measures have been tracked for the prototype data environment, but a formal evaluation using the evaluation framework has not been conducted.
- Other testing opportunities include the Reference Model, the Clarus Initiative, the Safety pilot project, or the high priority mobility applications that have been identified.

Issues faced during field testing should be documented and used to revise the evaluation framework as needed. These include the following:

- Vendor's risk
- Intellectual Property Rights
- Privacy
- Liability
- Security and access
- Ownership of Data
- Implied Consent
- Governance (i.e. policies, strategies, roles and responsibilities at various levels)
- Data Archiving

# Chapter 4 Lessons Learned

~~This section will document technical and non-technical lessons learned during the prototype implementation period (to be completed in later updates of this report).~~

This report presents an evaluation framework that can be used to assess the activities of the DCM Program and the data sets and data environments that will be created as part of Phase II of the program. The evaluation framework focuses on how well data sets and data environments support the applications developed through the Dynamic Mobility Applications Program. It is not intended to evaluate the applications themselves, although it is feasible that the same steps could be applied in such an evaluation.

Field testing of the evaluation framework has not been completed; however, an evaluation meeting with stakeholders on November 23, 2011 yielded the following lessons learned to be considered moving forward:

- This evaluation framework is intended to be a dynamic document. It is evolving and will continue to change going forward. The measures and framework should continue to be tested and refined in Phase II (Research) and Phase III (Implementation) of the DCM Program.
- DCM Program stakeholders should reach out to the Dynamic Mobility Applications program to ensure the evaluation framework meets their needs and to identify appropriate evaluation questions and performance measures for inclusion in future updates of the framework.
- Use cases and operational scenarios developed as part of the systems engineering process can be used as a tool for conducting evaluations. Operational scenarios describe how various networks and stakeholders are expected to operate once a data environment (or application) is in place. An operational scenario is similar to a logic model in that it describes the situation and expected outcomes, as well as the program activities and resources required to achieve these outcomes. The logic model can then be used as a high-level roadmap for conducting the evaluation.



## **APPENDIX A. Mapping of Data Environment Concept to Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) Technology Test Bed**

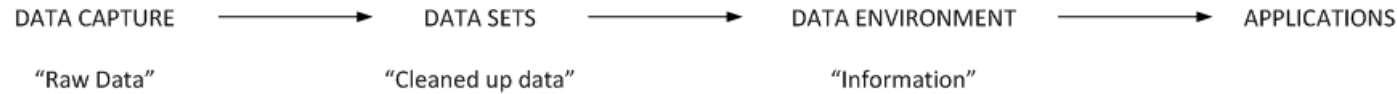
The *Data Capture and Management Program Vision: Objectives, Core Concepts and Projected Outcomes* report defines a data environment as:

- A well-organized collection of data of specific type and quality,
- Captured and stored at regular intervals from one or more sources, and
- Systematically shared in support of one or more applications.

A data environment is essentially a data warehouse or real-time data feed that will be accessible to stakeholders via the Internet through the Research Data Exchange (currently in development). A data environment is made up of one or more data sets, which consist of observed data, or a combination of observed, derived, and/or simulated data from a broad spectrum of data sources (travelers, vehicles, infrastructure, or simulation). Data sets are clearly organized and documented with metadata, and are made broadly available to researchers and application developers under open data licenses. The differences between data sets and data environments is further explained in the following diagrams. The diagrams map these concepts to the prototype data sets and data environment (Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) Technology Test Bed.)

Figure 2. Data Environment Concept

**DATA ENVIRONMENT CONCEPT:**



**Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) Technology Test Bed:**

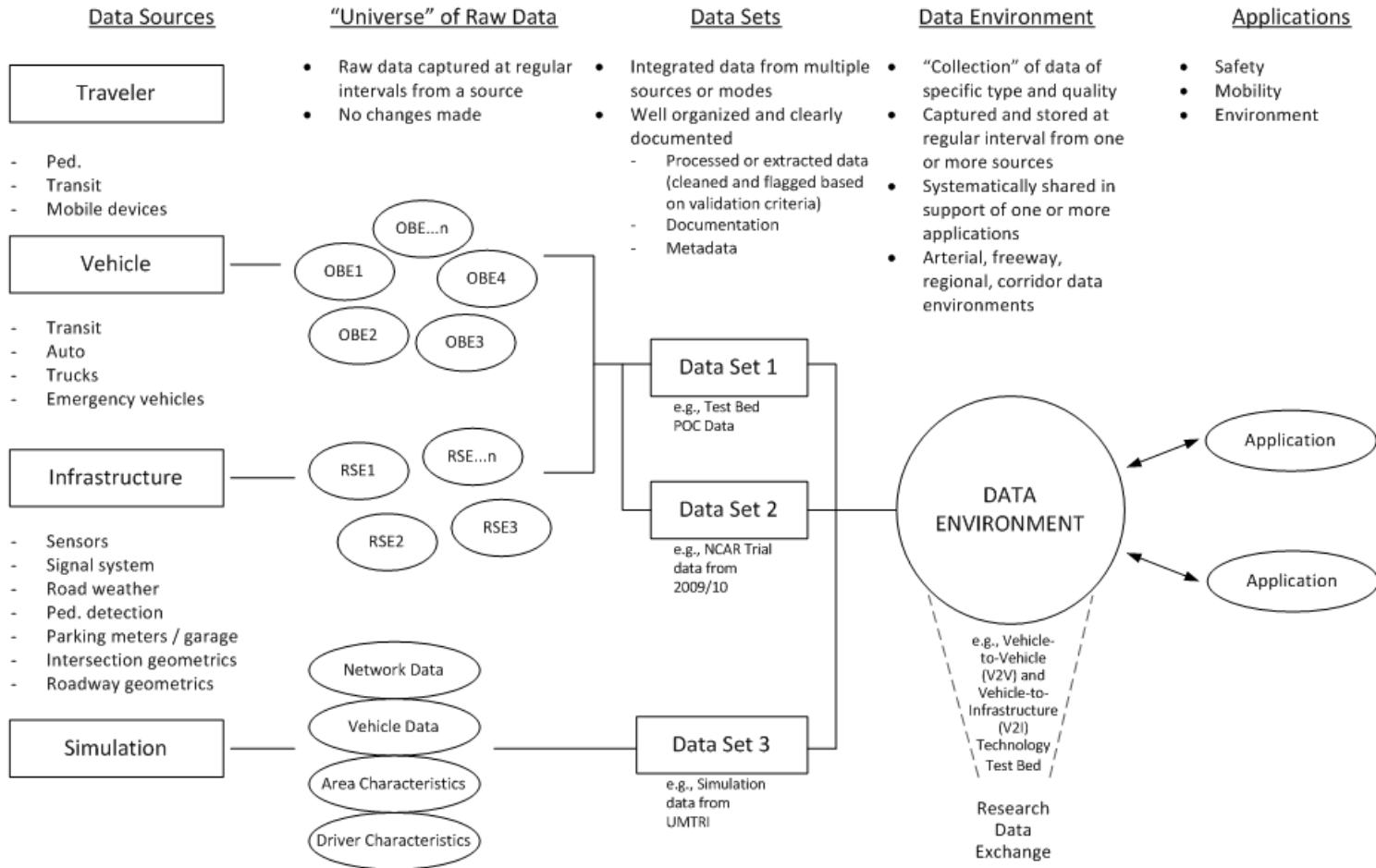
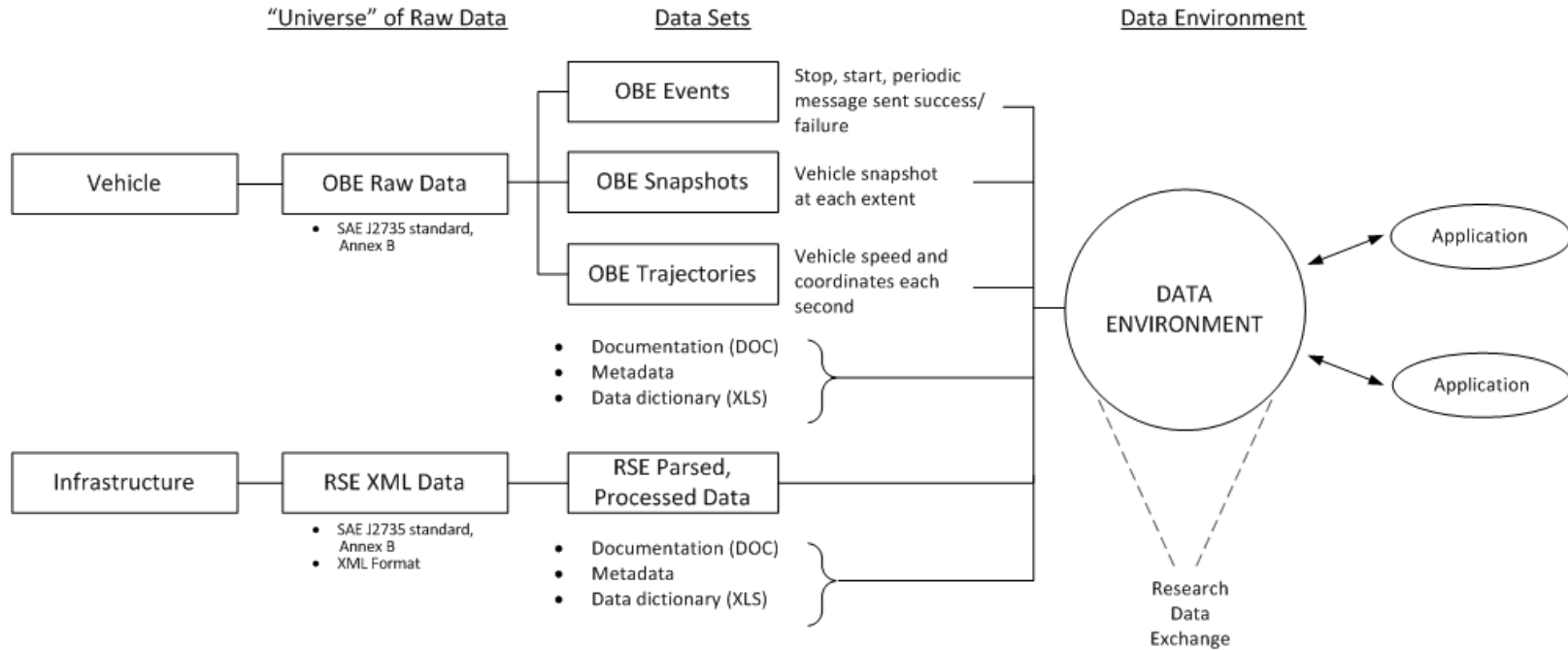


Figure 3. Test Bed for Vehicle Research

Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) Technology Test Bed:



## APPENDIX B. Example Evaluation Framework for a Regional (Information) Data Environment

As part of the Dynamic Mobility Applications Program, FHWA is working with the research community to develop test data sets and a regional (information) data environment to support the Multi-Modal Real-Time Traveler Information application for a region. This appendix describes an example evaluation framework that could be used to evaluate the test data sets and regional data environment in a research setting.

### **Step 1: Evaluation Scope and Timing**

An evaluation is needed to evaluate the data sets contained within the data environment, as well as the effectiveness of the data environment in supporting the desired application.

### **Step 2: Logic Model**

The following describes the logic model for a regional data environment:

- **Situation:** In the current situation, FHWA needs test data sets and data environments to support Multi-Modal Real-Time Traveler Information, which is a high priority application under the Dynamic Mobility Applications Program. The research community is assembling test data sets to support this effort. A DCM Program data manager needs to evaluate the test data sets to determine their suitability to support the targeted application and meet specific research objectives.
- **Inputs:** The test data set will be assembled from multiple sources and modes. Infrastructure data sources will include data from in-pavement or roadside speed, volume, or occupancy sensors; control systems (e.g., traffic signal controller, ramp meters, dynamic message signs); transit facility data (data from bus and rail stops, fixed guideways, etc.); and weather, work zone, and incident road closure data. Vehicle data sources will include private vehicles and transit vehicles. Traveler data sources will include transit passengers and travelers with mobile devices.
- **Outputs:** The DCM program would like one combined source of clean, integrated, multi-modal regional travel time data.
- **Outcomes:** The expected short-term outcomes are that the regional data environment has value, is utilized by stakeholders, and supports the required outcomes of the Multi-Modal Real-Time Traveler Information application. Another short-term outcome is the provision of well-organized data and clear rules for participation. A medium-term outcome is one that the regional data environment supports the development of new applications. In the long-term, these can be transitioned to an operational environment.

An example logic model for evaluating a regional data environment is shown in Figure 4.

### **Step 3: Evaluation Questions**

For the evaluation of a regional data environment, the DCM data manager seek answers to the following evaluation questions:

- **Inputs:** For data capture, how well is data being collected? Are data collection protocols being met? Are open source standards being followed? Are data quality parameters being assessed?
- **Outputs:** For data sets within the data environment, how well is data organized and assembled? Are data sets fully documented with metadata? How well is data being integrated with other sources?
- **Outcomes:** For the data environment, is data contained within the data environment being utilized by targeted applications? Does the data environment support the expected outcomes of applications (e.g., ATIS)?

Figure 4 illustrates how the evaluation questions relate to the inputs, outputs, and outcomes of the logic model.

### **Step 4: Identify Performance Measures**

The following performance measures are selected from Tables 1 through 3 to support the evaluation questions above:

- **Inputs:** Percent of data sets that meet required data collection protocols for various types of data; and percent of data sets that meet latency and coverage requirements needed to support the applications.
- **Outputs:** Percent of data sets (within this particular data environment) with complete metadata and documentation; percent of data sets verified for data quality; percent of data sets that meet open source data standards; percent of data sets that are real-time; and level of satisfaction with the ability to integrate data sets from different modes.
- **Outcomes:** Percent of data sets utilized within the data environment; number of applications used by the data environment; number of multi-modal applications used by the data environment; number of real-time applications used by the data environment; and number of non-program data environments required to support target applications.

Figure 4 illustrates how the performance measures relate to the inputs, outputs, and outcomes of the logic models, as well as the evaluation questions identified in Step 3.

### **Step 5: Data Collection Parameters**

The DCM data manager consults Tables 1 through 3 to identify the data requirements, potential data sources, and survey mechanisms required to support calculation of the output and outcome performance measures. Required data elements are collected.

**Step 6: Performance Measure Results**

The performance measures are calculated for each of the desired outputs and outcomes.

**Step 7: Data Quality Targets**

The DCM data manager utilizes the Reference Model to ensure that data quality targets are being met for each of the data sets contained in the data environment.

**Step 8: Benefit-Cost**

The DCM data manager conducts a benefit-cost/risk management exercise for the data environment. They quantify the cost to provide the data environment, including set up costs, hardware and software, as well as life cycle costs associated with updating and maintaining the data. Benefits are expressed in terms of the impacts of not having the data. The risk management approach in Appendix D is applied to identify and assess risks.

**Step 9. Summarize evaluation results**

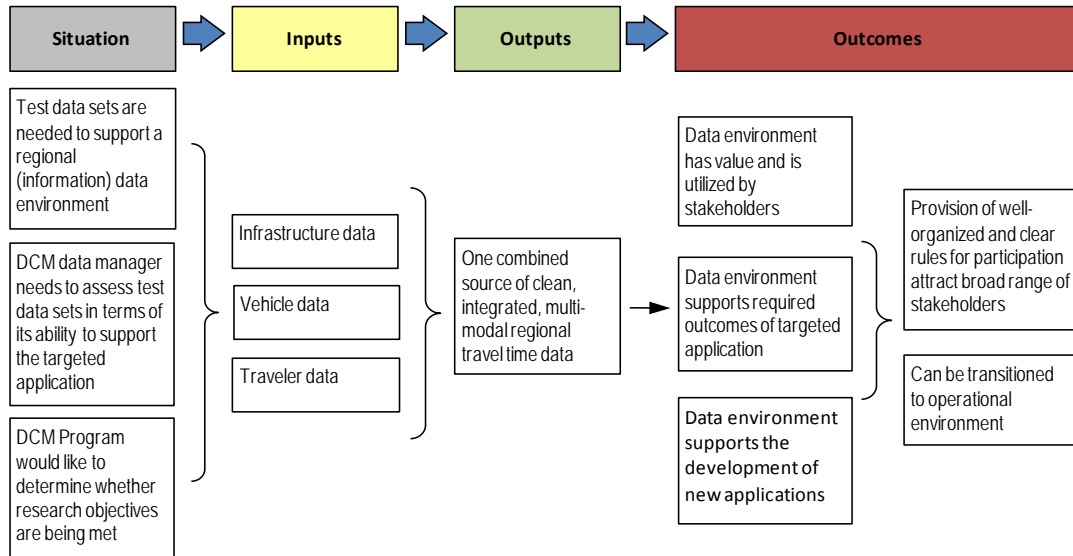
Evaluation results are summarized in a brief technical memorandum designed for internal use.

**Step 10. Complete the feedback cycle**

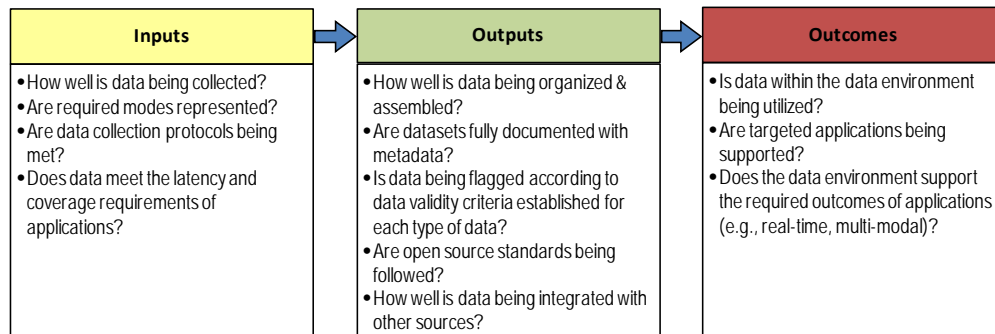
Evaluation results are used to communicate significant achievements in the development of the Multi-Modal Real-Time Traveler Information application, and it is used to make improvements in the collection of data from the available sources.

**Figure 4. Evaluation Framework for Regional Data Environment**

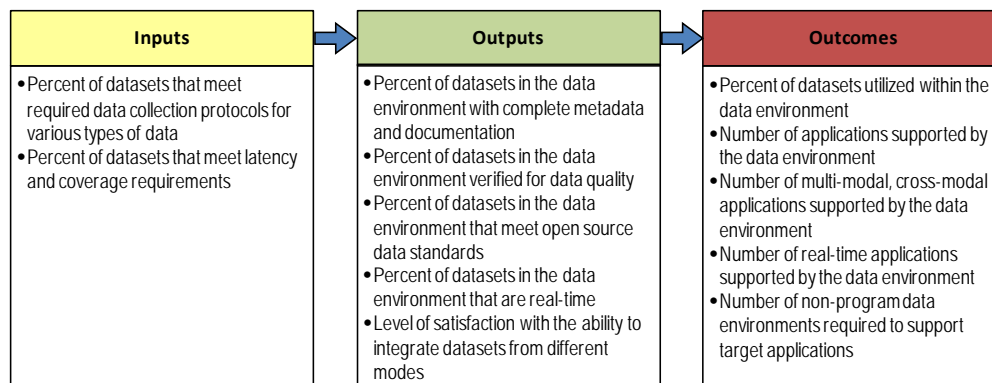
Example Logic Model:



Example Evaluation Questions:



Example Performance Measures:



## APPENDIX C. Example Evaluation Framework for the DCM Program

Program staff seek to demonstrate progress and significant achievements within each of the program tracks for the DCM Program, and to determine whether the program should progress to Phase III. This appendix describes an example evaluation framework that could be used to evaluate the effectiveness of the DCM Program.

### ***Step 1: Evaluation Scope and Timing***

An evaluation is needed to evaluate the progress and significant achievements for each of the program tracks within the DCM Program. The evaluation takes place at the conclusion of Phase II of the program.

### ***Step 2: Logic Model***

An example logic model for evaluating the DCM Program is shown in Figure 5. The logic model for the DCM Program is organized vertically rather than linearly and depicts the program activities (outputs) and expected outcomes for each program track. The following describes the logic model for standards development to be conducted as part of Track 2 (fourth column in the logic model):

- ***Program Activities (Outputs):*** Program activities include developing guidelines for data collection protocols for each data source/type of data based on national and international standard message sets and interfaces; developing validation criteria for data quality flagging; developing minimum criteria and standards for metadata and data dictionaries; developing minimum criteria and standards for data set documentation; and developing a Reference Model for a well qualified data set.
- ***Short-Term Outcomes:*** The expected short-term outcomes would encompass changes in skills, knowledge, and awareness as a result of program activities. For example, contributors have a clear understanding of data collection protocols, metadata, data dictionary, and documentation requirements; unambiguous metrics and a systematic methodology for validating data quality are established and adopted by stakeholders; and contributors have a clear understanding of the requirements for a well qualified data set.
- ***Medium-Term Outcomes:*** The expected medium-term outcomes would encompass changes in practices, policies, and procedures as a result of increased knowledge and awareness. For example, data sets would be collected and shared using data collection protocol standards; data sets would be systematically flagged for data quality and validity; and data sets would be fully documented with metadata, data dictionaries, and other supporting documentation.

### ***Step 3: Evaluation Questions***

For the evaluation of the DCM Program, staff and public/private partners might be interested in the following evaluation questions for standards development as part of Track 2:



- **Program Activities (Outputs):** Is the program accomplishing its activities related to standards development?
- **Outcomes:** To what extent are stakeholders implementing adopted standards in their data collection practices? How well is data organized and assembled across all data sets? Are data sets fully documented with metadata?

#### **Step 4: Select Performance Measures**

Figure 5 provides a clear mapping for each program track to the output and outcome performance measures summarized in Tables 1 – 3. The following performance measures support the evaluation questions for standards development as part of Track 2:

- **Program Activities (Outputs):** Achievement of specific program activities related to standards development.
- **Outcomes:** Percent of data sets (across all data environments) that meet data collection protocols; percent of data sets with complete metadata and documentation; percent of data sets verified for data quality; and percent of data sets that meet open source data standards.

#### **Step 5: Data Collection Parameters**

DCM Program staff consult Tables 1 through 3 to identify the data requirements, potential data sources, and survey mechanisms required to support calculation of the output and outcome performance measures. Required data elements are collected.

#### **Step 6: Performance Measure Results**

The performance measures are calculated for each of the desired outputs and outcomes.

#### **Step 7: Data Quality Targets**

DCM Program staff identify and apply data quality targets from the Reference Model development as applicable to the evaluation.

#### **Step 8: Benefit-Cost**

DCM Program staff conduct a benefit-cost/risk management exercise for the program. They quantify the cost to provide the data environment, including set up costs, hardware and software, as well as life cycle costs associated with updating and maintaining the data. A risk management approach is used to determine the perceived value of the data environments developed through the program. The risk management approach in Appendix D is applied to identify and assess risks.

#### **Step 9. Summarize evaluation results**

Evaluation results are summarized in an evaluation report designed for internal and external use.

#### **Step 10. Complete the feedback cycle**

Evaluation results are used to communicate significant achievements of the DCM program to decision makers, and it is used to decide whether the program will proceed to Phase III.

Figure 5. Example Logic Model for the DCM Program Evaluation

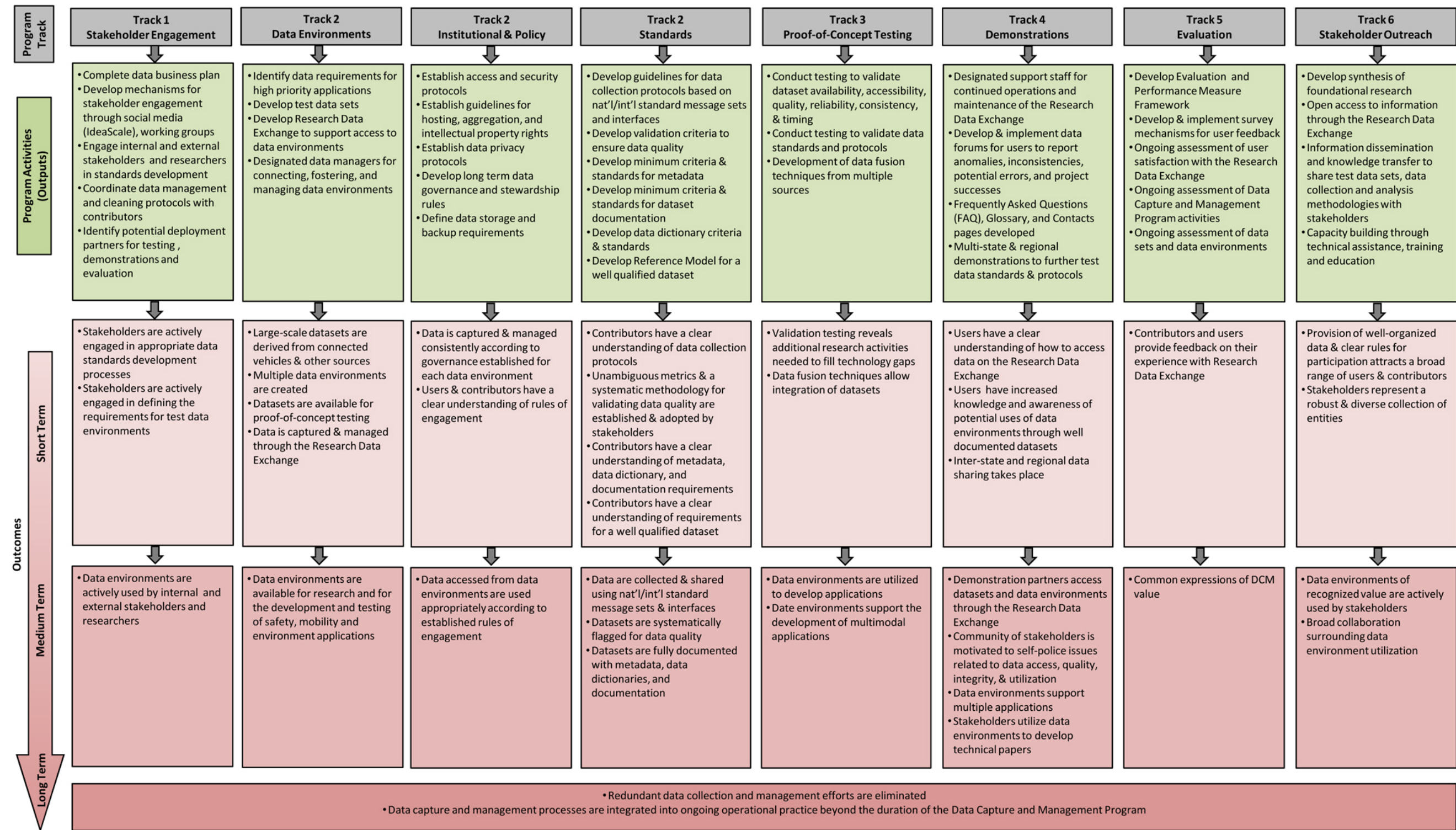
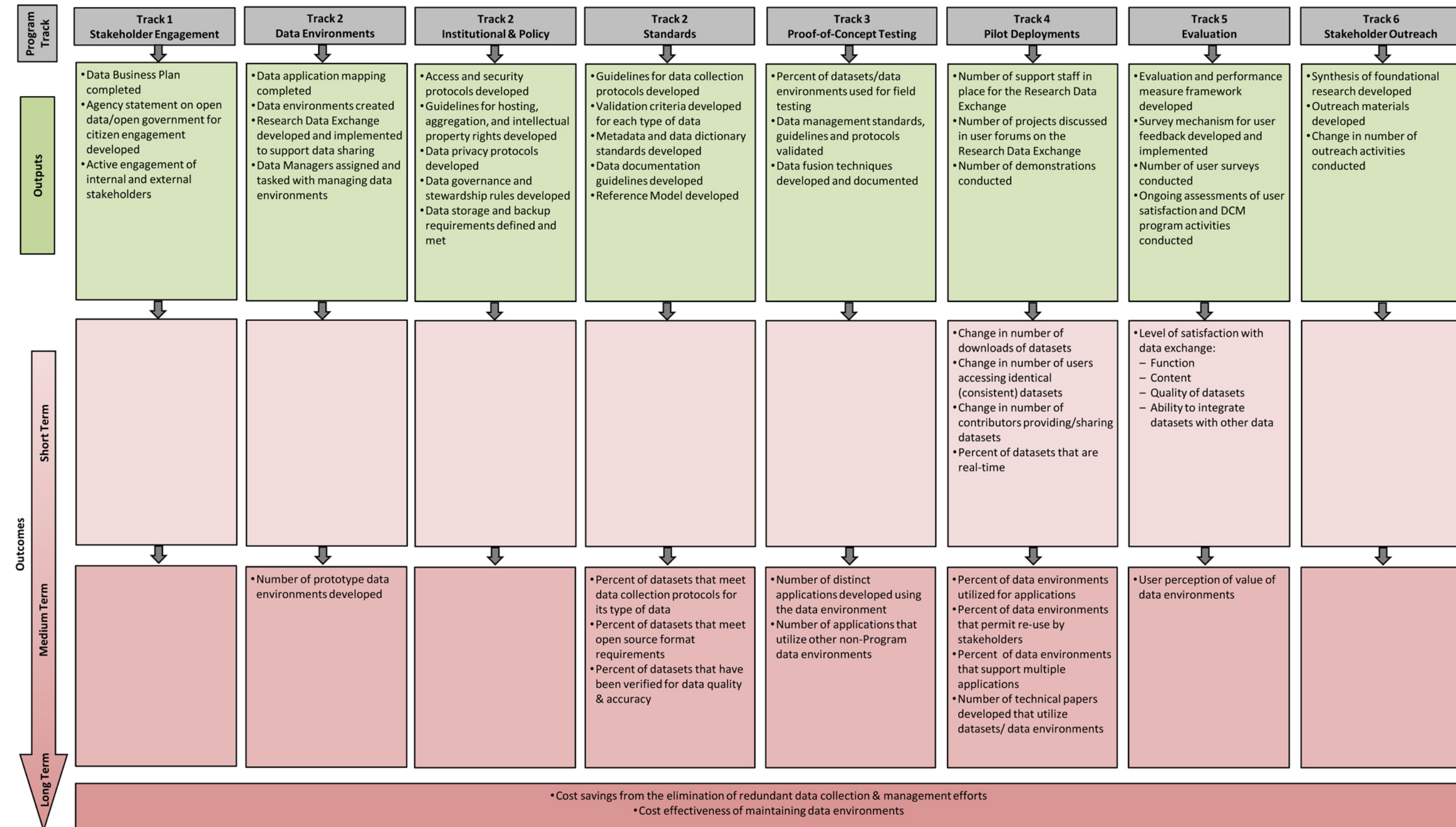




Figure 6. Example Performance Measures for the DCM Program Evaluation



## APPENDIX D. Risk Management Framework

### *Benefit-Cost/Risk Management for Data Programs*

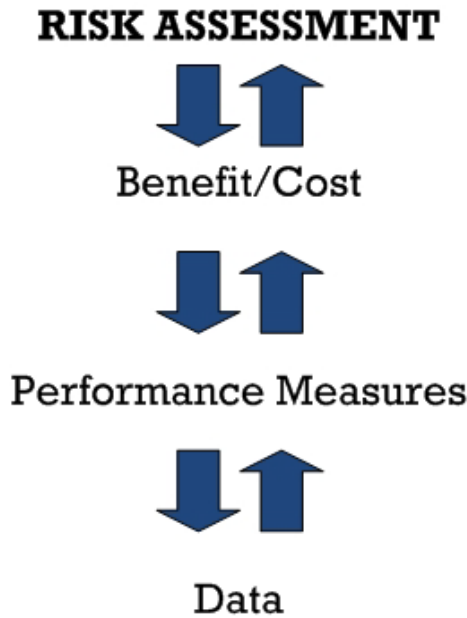
Determination of the benefits of data programs relative to their cost is a challenging exercise. While tools and methodologies exist for determining the benefit/cost ratio of projects to use in transportation project selection and evaluation, the same is not true for data programs. However, data programs are becoming increasingly important to transportation agencies and they are responding by developing methods to value their data. For example, many states are establishing Data Business Plans that include value assessments of data sets and programs. Quantifying the cost of data programs and data sets is straightforward. The benefits (or perceived benefits) of data are more challenging to determine. States are using risk management approaches to determine the perceived value of data. This appendix discusses a potential risk management process and how a well-defined risk management program could be applied to protect the DCM Program.

A strong risk management program will be guided by several data management principles, with the first principle being that data shall be managed as an asset. Establishing a risk management program requires identifying a risk management framework and the technology tools and business processes that are used to support risk management. Each of these components are examined in the following sections.

A discussion of risk management begins with a definition of risk. At a presentation of the Transportation Research Board (TRB) July 2009 meeting, Keith R. Molenaar, PhD, University of Colorado, defined risk as “an uncertain event or condition that, if it occurs, has a negative or positive effect on a project’s objectives.”

Risk management programs provide a vital link between data systems, performance measurement, and target setting. Risk assessment is part of the risk management process. This assessment includes access to data, which is used to develop performance measures and to perform cost/benefit analysis as illustrated in Figure 7.

**Figure 7. Data, Performance Measures, and Risk Management**

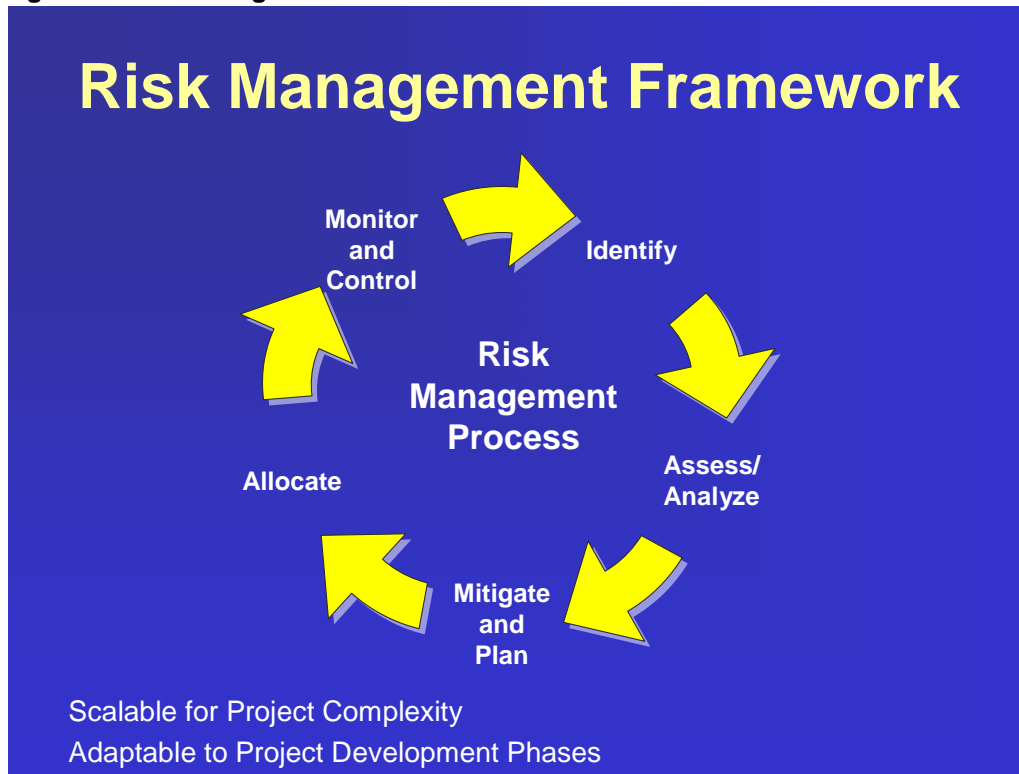


This relationship is an iterative one which requires continuous evaluation of data sets and performance measures and a refinement and adjustment of risk priorities.

This link between data and risk management is a critical one, especially when data is needed to support performance measures and cost/benefit analysis, and the necessary information may not be available due to intermittent network interruptions, or to catastrophic events. Risk management helps to identify when, where, and how these types of events may occur. This allows for the development of strategies to deal with any potential risks to agency assets including data program assets.

A risk management program focuses on risk tolerance, the level of decision-making, and asks questions such as “how do you make tradeoffs with data and decision making?”

Figure 8 illustrates a typical process for assessing risks within the context of a standard risk management framework. This specific example is drawn from Molenaar’s presentation addressing risks associated with project development and controlling costs; however, the same fundamental elements should be included in any risk management process/framework.

**Figure 8. Risk Management Framework**

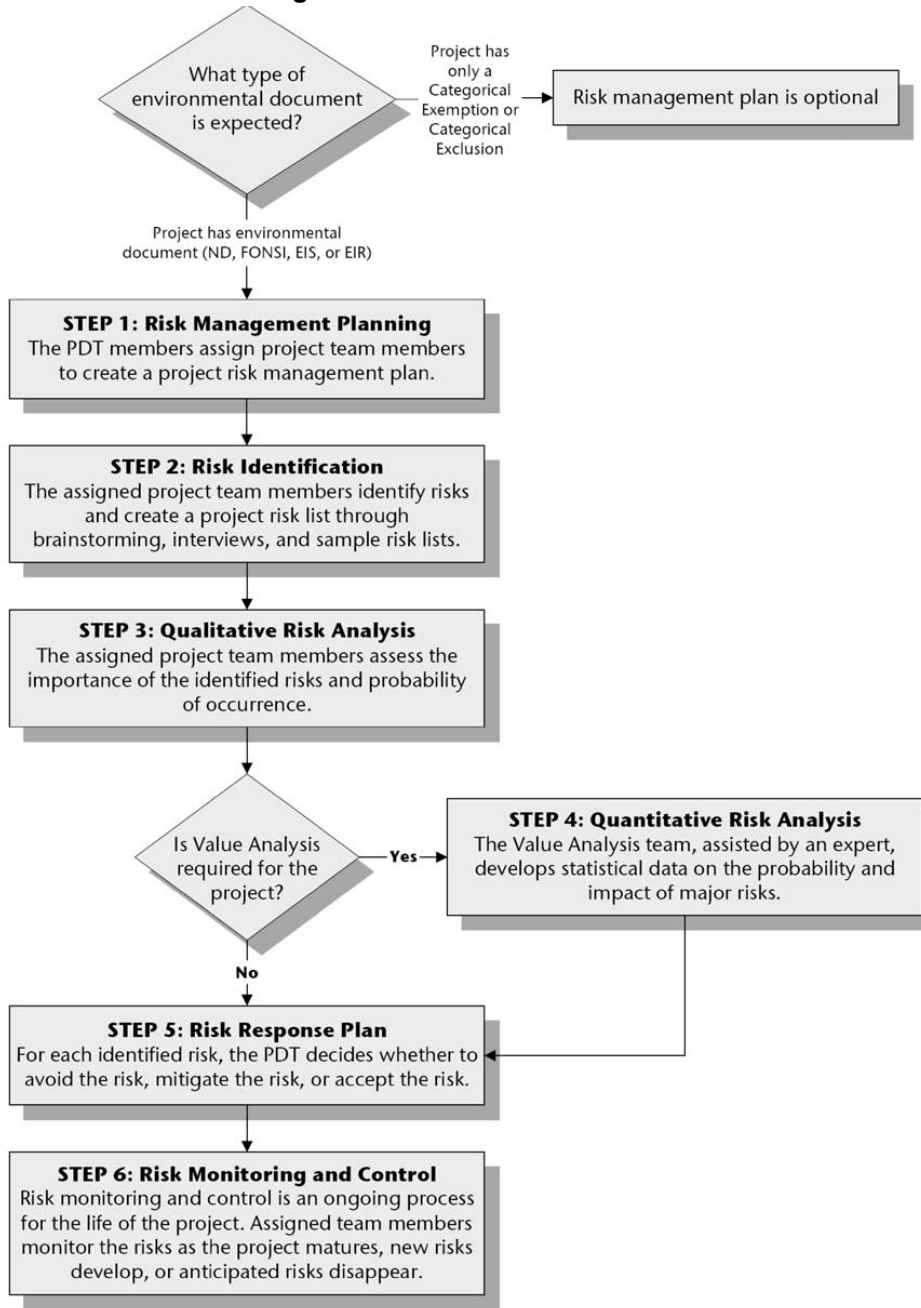
Source: Keith R. Molenaar, PhD, July 2009

### ***Example Risk Management Framework***

An excellent source of additional information on Risk Management and Strategies for Risk Management is *NCHRP Report 574: Guidance for Cost Estimation and Management for Highway Projects During Planning, Programming, and Preconstruction*. Although the information in that report pertains to highway projects, it could also be directly applicable to developing risk strategies and tools for managing risks associated with the DCM Program.

The Project Risk Management Handbook, 2<sup>nd</sup> ed, developed and updated by Caltrans in 2007 was presented as a case study in the report. In the Caltrans process, the project team completes the risk management plan before the project initiation document (PID) component ends. The team updates the plan in each subsequent lifecycle component and continues to monitor and control risks throughout the life of the project. Figure 9 shows the Caltrans risk management process flowchart.

**Figure 9. Caltrans Risk Management Flowchart**



Notes: PT = Project development team, EIS = Environmental impact statement, ND = Negative declaration, FONSI = Finding of no significant impact, EIR = Environmental impact report  
 Source: Project Risk Management Handbook, Caltrans Office of Project Management Process Improvement, 2007.

## APPENDIX E. Risk Management Tools

There are many technology tools and business processes that can be used to manage risks. These include, but, are not limited to risk registers, dashboards (i.e., COGNOS), scorecards and knowledge management systems. Key staff familiar with the work-flow processes associated with the collection, maintenance, and reporting requirements for critical data systems, are also a source in developing strategies to manage risks. Regular brainstorming sessions and interviews with data stewards, who are responsible for maintaining data sets, can yield a red flag list which identifies potential and known risks to any of the data sets. This combined approach using technology tools and documented business processes will help to manage potential risks to the DCM Program.

A Risk Register, similar to the one illustrated in Figure 10 from Keith R. Molenaar (Presentation on Risk Analysis Tools and Management Practices to Control Transportation Project Costs, July 2009), should be developed for the DCM Program.

In this example each risk is identified with a priority number, status, ID#, date the risk was identified, the functional area responsible to handle the risk, statement of the threat (risk), details of the risk, risk trigger, and the type of Qualitative Analysis to be done on the risk, including the type of analysis, probability of risk to the program due to lack of information, data, resources to address the risk, and impact to the program if the risk is not addressed.



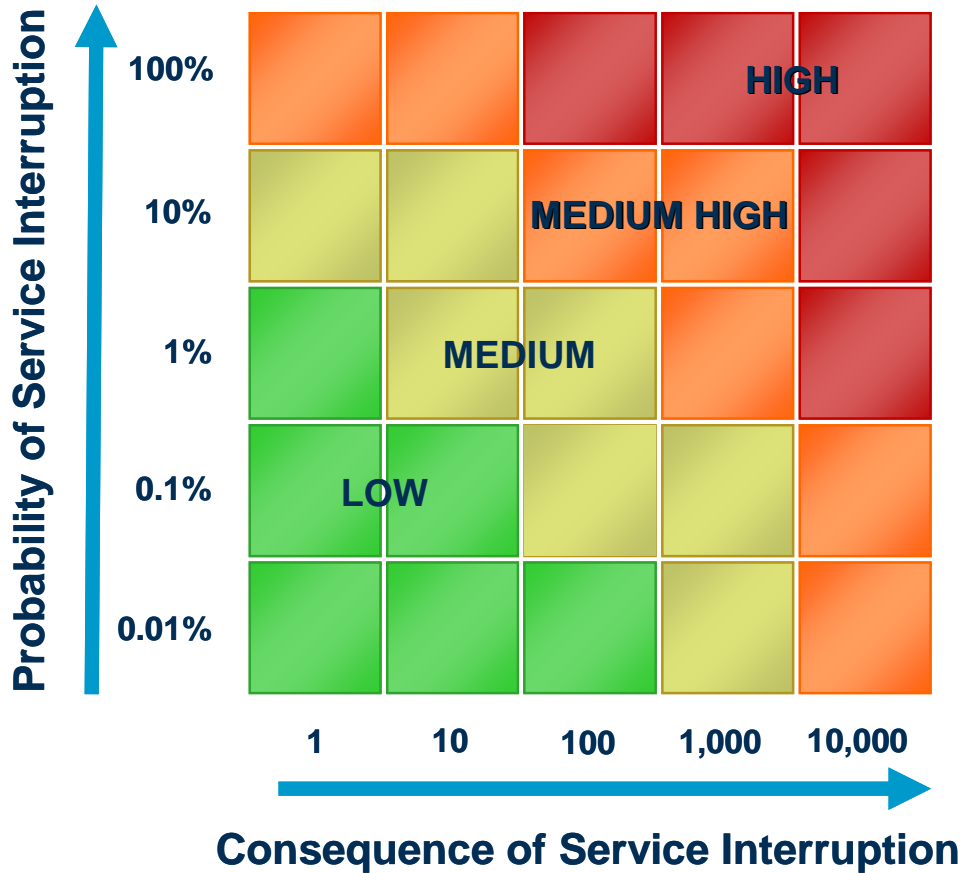
Figure 10. Example Risk Register

PROJECT RISK MANAGEMENT PLAN											
Priority	Identification						Qualitative Analysis				
	Status	ID #	Date Identified Project Phase	Functional Assignment	Threat/Opportunity Event	SMART Column	Risk Trigger	Type	Probability	Impact	Risk Matrix
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
1	Active	3c	8/7/2002  PID	Environmental Analysis	Residents will want a higher soundwall than needed to mitigate noise.	The height of the proposed soundwall is 2 meters. Residents who live next to the freeway have expressed a desire for a 5 meter high wall.	Risk is occurring if the Revised Noise Study indicates the additional wall height is warranted.	Schedule  Cost	High	High	

Source: Keith R. Molenaar, PhD, July 2009

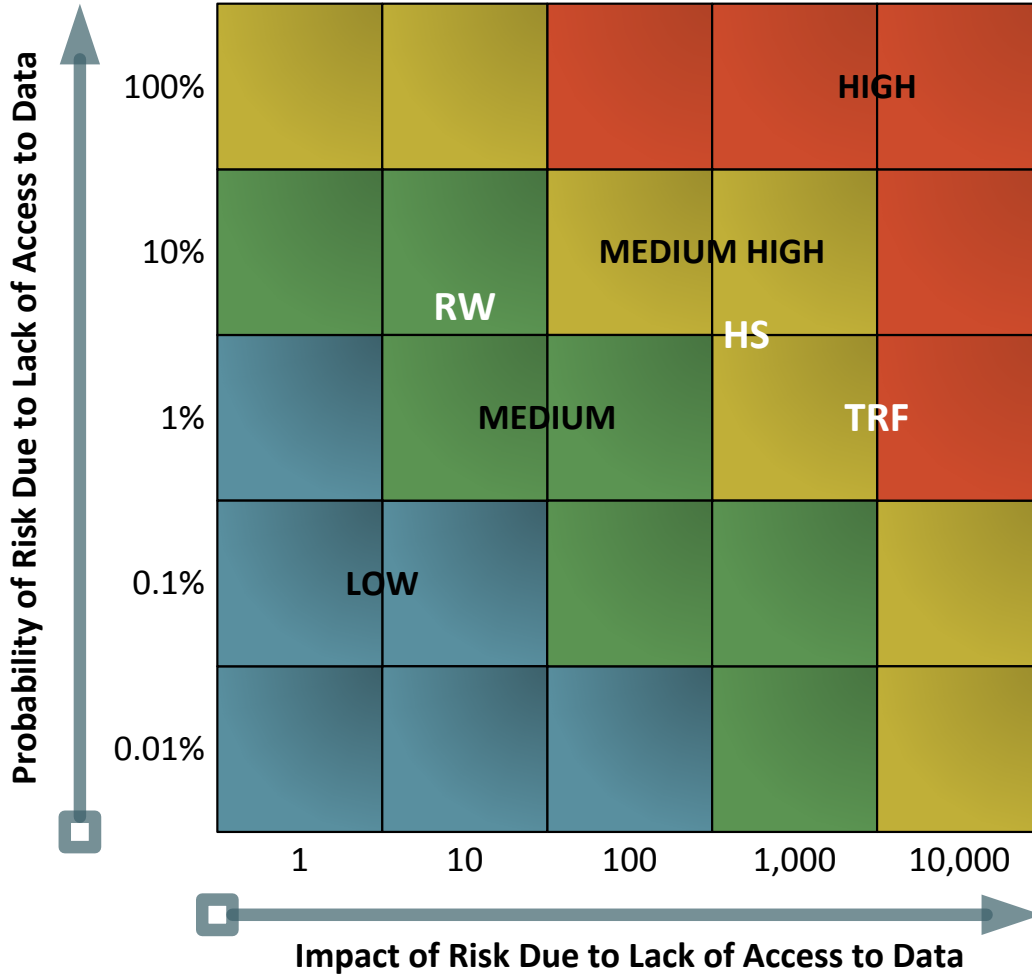
One of the components of the Risk Register, is a Risk Impact Matrix. A Risk Impact Matrix is a tool which defines a two-dimensional risk universe, as illustrated in Figure 11. The risk universe describes potential risks associated with a particular asset (e.g., bridges and the potential for bridge failure). The two dimensions are: (1) probability of service interruption, or, in the case of data systems, the probability of lack of access to the system during a twelve-month period for instance from the time the risk is identified, and (2) consequence of service interruption, or impact to the program due to the interruption of access to needed data over the same twelve-month period. The purpose of the risk impact matrix is to focus attention on both probability and consequence of risks.

Figure 11. Example Risk Impact Matrix



A similar risk impact matrix could be defined for the data systems that support the DCM Program. For example, Figure 12 illustrates that while an interruption of Road Weather (RW) data may be more likely than Highway Safety (HS) or Traffic (TRF) data, the impact of lack of access to RW data is less than the loss of the other two types of data systems. Again, this example is for illustrative purposes only and a more in-depth analysis should be done by the DCM Program as part of the overall risk management strategy.

**Figure 12. Example Risk Impact Matrix for a Data Program**



## APPENDIX F. Risk Management Approach

A risk management program would serve to strengthen the overall DCM Program and protect USDOT's investment in critical datasets and data environments.

In the context of the DCM Program, the recommended steps for identifying and assessing risks include the following:

- **Step 1. Identify risks.** Risks include the impact of not having the data set/environment or having the data but at varying levels of quality (timeliness, accuracy, completeness, availability, validity, timeliness coverage)
- **Step 2. Assess/analyze the risks associated with the data systems.** This step involves determining the relative frequency and severity of any potential risk and ranking those risks in a priority order, so that a plan can be developed to address those risks.
- **Step 3. Develop a plan to mitigate those risks.** This plan will involve identifying specific actions to be taken in the event of loss of any of the datasets, in terms of the impact to the DCM Program, program stakeholders, and the public. The plan would also include assigning responsibility or ownership of the risks to specific offices or individuals within USDOT or the DCM Program to manage those risks. The Risk Management plan for the DCM Program should include standard back-up and recovery procedures for critical datasets and off-site duplicate databases for priority datasets..
- **Step 4. Allocate necessary resources to manage the risks.** The DCM Program should consider the allocation of an appropriate portion of the DCM budget to establishing an action plan to manage risks associated with the data capture and management processes.
- **Step 5. Ongoing monitoring and control of potential risks.** The final step requires ongoing monitoring and control of potential risks to data programs. The DCM Program should consider using electronic dashboards, scorecards and other tools to monitor any potential risks to the core datasets and data environments.

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