Guide to Life-Cycle Data and Information Sharing Workflows for Transportation Assets

Final Report
September 2018

CONSTRUCTION MANAGEMENT AND TECHNOLOGY

Sponsored by
Iowa Highway Research Board
(IHRB Project TR-714)
Iowa Department of Transportation
(InTrans Project 16-584)
Midwest Transportation Center
U.S. Department of Transportation Office of the Assistant Secretary for Research and Technology

MIDWEST TRANSPORTATION CENTER

IOWA STATE UNIVERSITY
Institute for Transportation

About CMAT

The mission of the Construction Management and Technology (CMAT) program is to improve the efficiency and cost-effectiveness of planning, designing, constructing, and operating transportation facilities through innovative construction processes and technologies.

About MTC

The Midwest Transportation Center (MTC) is a regional University Transportation Center (UTC) sponsored by the U.S. Department of Transportation Office of the Assistant Secretary for Research and Technology (USDOT/OST-R). The mission of the UTC program is to advance U.S. technology and expertise in the many disciplines comprising transportation through the mechanisms of education, research, and technology transfer at university-based centers of excellence. Iowa State University, through its Institute for Transportation (InTrans), is the MTC lead institution.

The preparation of this report was financed in part through funds provided by the Iowa Department of Transportation through its "Second Revised Agreement for the Management of Research Conducted by Iowa State University for the Iowa Department of Transportation" and its amendments.

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
IHRB Project TR-714		

4. Title and Subtitle Guide to Life-Cycle Data and Information Sharing Workflows for Transportation Assets	**5. Report Date** September 2018 6. Performing Organization Code
7. Author(s) H. David Jeong (orcid.org/0000-0003-4074-1869), Charles Jahren (orcid.org/0000-0003-2828-8483), Jennifer Shane (orcid.org/0000-0002-2612-4269), Kristen Cetin (orcid.org/0000-0003-2662-8480), Tuyen Le (orcid.org/0000-0002-8606-9214), and Chau Le (orcid.org/0000-0002-2582-2671)	**8. Performing Organization Report No.** InTrans Project 16-584
9. Performing Organization Name and Address Construction Management and Technology Program Institute for Transportation Iowa State University 2711 South Loop Drive, Suite 4700 Ames, IA 50010-8664	**10. Work Unit No. (TRAIS)** **11. Contract or Grant No.** Part of DTRT13-G-UTC37
12. Sponsoring Organization Name and Address Iowa Highway Research Board Iowa Department of Transportation 800 Lincoln Way Ames, IA 50010 Midwest Transportation Center 2711 S. Loop Drive, Suite 4700 Ames, IA 50010-8664 U.S. Department of Transportation Office of the Assistant Secretary for Research and Technology 1200 New Jersey Avenue, SE Washington, DC 20590	**13. Type of Report and Period Covered** Final Report **14. Sponsoring Agency Code** IHRB Project TR-714

15. Supplementary Notes

Visit www.intrans.iastate.edu for color pdfs of this and other research reports.

16. Abstract

Thanks to an array of advanced digital technologies, much of today's transportation project data are available in digital format. However, due to the fragmented nature of the highway project delivery process, the growing amount of digital data is being archived and managed separately. This makes it difficult for professionals to take full advantage of the efficiencies of digitized data and information. The purpose of this research was to identify current data workflows and areas for improvement for five of the most common types of highway assets—signs, guardrails, culverts, pavements, and bridges—and offer guidance to practitioners on how to better collect, manage, and exchange asset data.

The research team conducted focus group discussions and interviews with highway professionals to capture their knowledge and practices about the data workflows. In addition, the team conducted an extensive review of the literature, manuals, project documents, and software applications regarding the exchanged information. For each type of asset, an information delivery manual (IDM) was developed. Each IDM consists of several process maps (PMs) and one exchange requirement (ER) matrix. A total of 15 PMs and 5 ER matrices were developed.

A set of limitations in current data workflows was identified and a set of recommendations to overcome those limitations was also determined and documented. The conclusion was that current data workflows were designed mostly for contract administration purposes. Thus, more efficient asset-centric data workflows need to be implemented to truly streamline the data workflows throughout an asset's life cycle and minimize wasted resources in recreating data in the asset maintenance stage.

17. Key Words	18. Distribution Statement
data exchange requirement (ER)—digital files—digital terrain models—life-cycle analysis (LCA)—project workflow—transportation asset management	No restrictions.

19. Security Classification (of this report)	20. Security Classification (of this page)	21. No. of Pages	22. Price
Unclassified.	Unclassified.	102	NA

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

GUIDE TO LIFE-CYCLE DATA AND INFORMATION SHARING WORKFLOWS FOR TRANSPORTATION ASSETS

Final Report
September 2018

Principal Investigator
H. David Jeong, Professor
Construction Management and Technology Program, Iowa State University

Co-Principal Investigators
Charles Jahren, Professor
Jennifer Shane, Associate Professor and Director
Kristen Cetin, Assistant Professor
Construction Management and Technology Program, Iowa State University

Authors
H. David Jeong, Charles Jahren, Jennifer Shane, Kristen Cetin, Tuyen Le, and Chau Le

Sponsored by
Iowa Highway Research Board
(IHRB Project TR-714),
Iowa Department of Transportation,
Midwest Transportation Center, and
U.S. Department of Transportation
Office of the Assistant Secretary for Research and Technology

Preparation of this report was financed in part
through funds provided by the Iowa Department of Transportation
through its Research Management Agreement with the
Institute for Transportation
(InTrans Project 16-584)

A report from
Institute for Transportation
Iowa State University
2711 South Loop Drive, Suite 4700
Ames, IA 50010-8664
Phone: 515-294-8103 / Fax: 515-294-0467
www.intrans.iastate.edu

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGMENTS

The authors would like to thank the Iowa Highway Research Board (IHRB), the Iowa Department of Transportation (DOT), the Institute for Transportation's Midwest Transportation Center at Iowa State University, and the U.S. Department of Transportation Office of the Assistant Secretary for Research and Technology for sponsoring this research.

EXECUTIVE SUMMARY

Despite the increasing availability of project data in digital format with the use of such advanced computerized technologies as 3D modeling and project administration systems, digital data and information are still being used and managed independently in proprietary formats by separate project participants. Data handover still relies heavily on paper or electronic paper-based documents. As a result, project data must be collected a second time in many cases, which increases the costs of data collection efforts. Understanding of project data life cycles is needed to properly transfer the appropriate data between project participants. The aim of this research was to help professionals working in the Iowa Department of Transportation (DOT) better understand the flow of digital data and information during the project life cycle for various types of transportation assets, including pavements, bridges, culverts, signs, and guardrails.

The research team conducted focus group discussions and interviews with highway professionals to capture their knowledge about the data workflows. In addition, an extensive review of the literature, manuals, project documents, and software applications regarding the exchanged information was conducted. For each type of asset, an information delivery manual (IDM) was developed. Each IDM consisted of several process maps (PMs) and one exchange requirement (ER) matrix. A total of 15 PMs and 5 ER matrices were developed for five different types of assets (i.e., signs, guardrails, culverts, pavements, and bridges). The PMs offered a better understanding of the overall workflow, particularly regarding the activities and the data sharing flow throughout a project. These PMs can help practitioners better understand the work process and interactions between involved parties for different types of projects (i.e., new construction, reconstruction, repair, and maintenance). The ER matrices showed who needs what data and who can provide the data. For example, from the maintenance point of view, asset location, geometry, material, and construction date are the data of greatest interest. These types of data were originally created by different actors, such as designers and contractors.

Some limitations within the current workflows were identified. For example, the flow of asset data (e.g., geographic locations) is disconnected between project phases, especially by a complete blockage between construction and asset management. Contractors create as-built data by adding red-line markups (i.e., not in machine-readable format) to the design PDF plans. This makes it difficult for the asset manager to translate the information into a useful format. Also, an ideal process map and suggestions for improvement were proposed to further streamline the workflows throughout the project life cycle and reduce duplicate data collection efforts during the operation and maintenance phases.

1. INTRODUCTION

1.1. Problem Statement

The adoption of various advanced computerized technologies such as three-dimensional (3D) modeling, light detection and ranging (LiDAR), and geographic information systems (GIS) is transforming the way we produce, exchange, and manage data and information throughout the life cycle of a transportation project. According to ample evidence and success stories from the vertical construction industry and some promising case study results from the highway industry, significant improvements in data and information sharing between project participants and across various project development stages are possible with a model-based project delivery process and electronic and digital data transfer systems. These improvements will, in turn, translate to increased productivity, more efficient project delivery, greater accountability, and improved asset management.

However, in current practice, digital data and information are being used and managed independently in proprietary formats by separate project participants, and data exchange processes still rely on paper or electronic paper-based formats rather than digital data sets. Several efforts have been made by the Federal Highway Administration (FHWA) through various webinar series to provide guidance and assistance for implementing digital modeling for highway projects, but there is not yet specific guidance on managing the flow of data and information across highway project phases. Research is needed to understand the current state of the practice in digital data sharing throughout the life cycle of a transportation project and to develop a guide on data flows, data sharing requirements, and supporting software applications and techniques to allow full reuse of digital data and information for particular use scenarios.

The goal of this research was to develop a guide to help professionals in the Iowa DOT understand the flow of digital data and information during the project life cycle for various types of transportation assets, such as pavements, bridges, culverts, signs, and guardrails. The resulting guidebook includes, but is not limited to, the following topics: (1) business use cases in which data sharing between project actors is needed; (2) business processes that define clear sequences of activities to be performed for data and information sharing and exchange, as well as expected outcomes; and (3) data requirements, data sources, levels of detail, and software applications and tools involved in specific data exchange use cases.

1.2. Research Approach and Methods

The objective of this study was to capture industry experts' knowledge and needs regarding digital data and information sharing during the life cycles of transportation assets. In order to achieve that objective, a literature review and focus group discussions were used extensively. A working group for each type of transportation asset was formed that included domain industry professionals with various kinds of expertise from the Iowa DOT (e.g., the Office of Design, the Office of Bridges and Structures, the Office of Contracts, maintenance staff, and district engineers) and contractors. In addition, workshops were held that involved software vendors (e.g., Bentley and AASHTOWare). These focus group discussions helped identify and document the data exchange scenarios, flows, requirements, and formats, along with supporting software applications. Based on the results of the discussions, a process map (PM) and a data map were developed for each scenario. The process map shows the data exchange processes throughout a project's life cycle, and the data map presents the data that must be shared, the stakeholders required to share the data, the stakeholders who receive the data, and the times when data must be shared.

To accomplish the research objectives, four tasks were performed (see Figure 1-1).

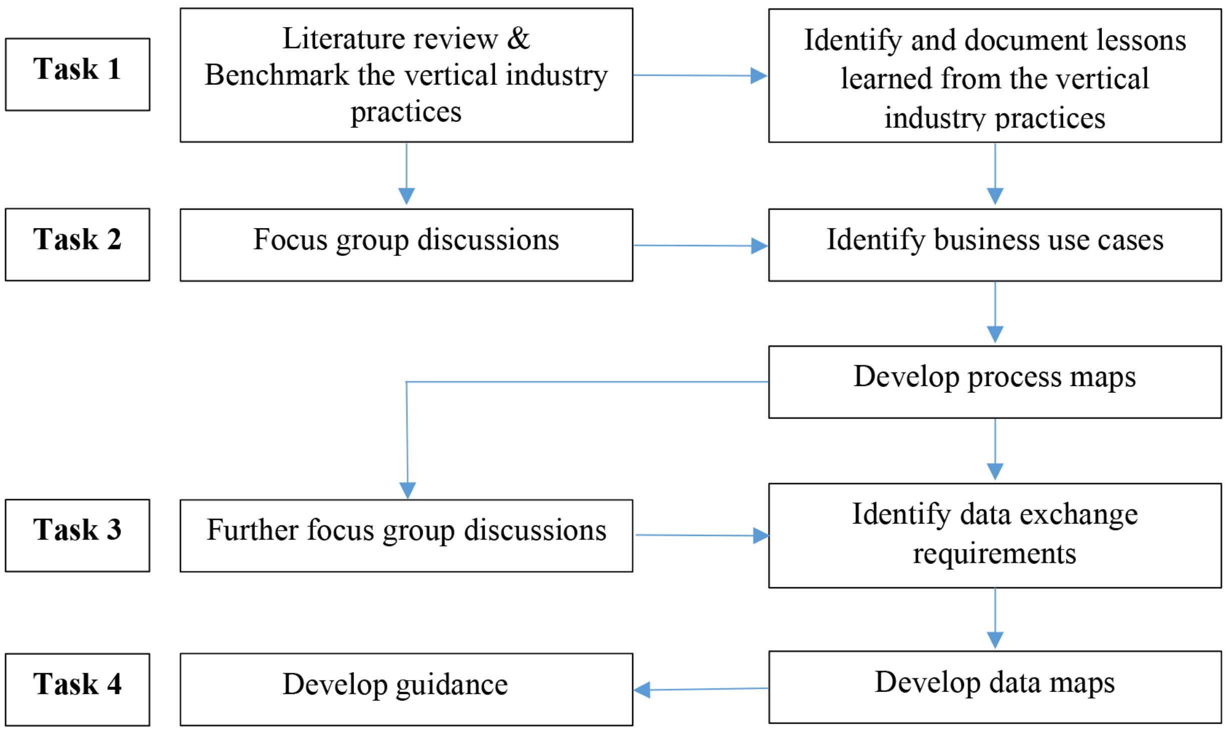

Figure 1-1. Flowchart of work tasks

1.2.1. Task 1: Literature Review and Benchmark the Vertical Industry Practices

The transportation sector lags behind the building construction sector in terms of data and information sharing between project participants and across various project development stages. The research team documented the best practices of the vertical construction industry through an extensive literature review and identified lessons learned and possible areas in which practices could be adapted to the highway infrastructure industry. As part of Task 1, IDMs were extensively studied and analyzed. An IDM aims to define (1) processes throughout the life cycle of a building project in which information exchange is required, (2) the actors that send and receive information for each process, and (3) definitions and descriptions for information to be shared (See et al. 2012). IDMs already are available, such as an IDM for the building programming phase and an IDM for geographical referencing (buildingSMART 2016). This guidance has been widely accepted as an industry standard in the building and facility construction and management sectors.

1.2.2. Task 2: Identify Business Use Case Narratives and Develop Process Maps

Focus group discussions were used to identify business use cases in which data sharing between project stakeholders (actors) would occur. For example, the "cost estimating" use case would need data sharing between the engineer and the cost estimator. Each identified scenario narrative was described in plain language and consisted of the following information: (1) project phase (e.g., design), actors involved (e.g., designers, estimators), activities (e.g., cost estimating), software platforms used (e.g., CAD), and the purposes of the activities and anticipated outcomes (e.g., total cost).

The research team translated the narratives obtained into formal process maps. The maps needed to be readable by both humans and machines so that the maps could be used for educating and training professionals and supporting the development of software tools to facilitate data sharing. Business process modeling notation (BPMN), which can visualize the relationships between activities, actors, and information flows (input and output), was employed to present the business workflows.

1.2.3. Task 3: Identify Data Exchange Requirements and Develop Data Maps

The focus group discussed how to identify data ERs based on the developed process maps. ERs specify the specific data to be shared, who is requesting the information, to whom the data must be sent, and the rationale for the data requests. Based on these discussions, the research team documented ERs in plain language at a level of detail that clearly defined the data entities (e.g., pavement layer), attributes (e.g., geometry information such as width and thickness), and specifications for each data item such that inconsistencies among the data names used by experts could be eliminated. Software applications that create and receive those data items were also identified by the focus group.

The data exchange requirements resulting from the discussions were used by the research team to develop data maps that visualize the network of linked data items through data ownership links (relationships between data and project actors or DOT divisions).

1.2.4. Task 4: Develop a Guide for Data and Information Sharing

With the successful completion of the tasks above, the research team developed guidance for DOTs on data sharing during the life cycles of transportation assets. The guidance includes the process maps and data maps along with plain language descriptions that clearly explain the following items:

- Business use cases where data sharing is needed
- Data and information requirements

- Detailed specifications for each data and information type
- Actors responsible for creating, receiving, validating, securing, and maintaining the data and information
- Software applications involved in each data transaction

2. LITERATURE REVIEW

2.1. Information Delivery Manuals

2.1.1. Business Use Case

A use case is defined as a scenario within the life cycle of a project in which data exchange between relevant stakeholders is required (Eastman et al. 2009). The key elements of a use case are the tasks to be completed, the actors (project stakeholders), and data exchange requirements that specify the data to be transferred to enable the completion of the work. Some examples of use cases are the data exchanges among architects, structural engineers, and HVAC engineers to develop an as-designed model; the data exchange between engineers and cost estimators to support quantity take-off and cost estimation; and the sharing of the design models with those involved in the energy analysis process. The identification of business use cases is the first step in developing an IDM for a given type of asset. For each of the identified use cases, an IDM is needed. Because a construction project involves an extensive number of phases and processes, business use cases are usually prioritized, and the top ones are developed first.

2.1.2. What Is an IDM?

An IDM aims to capture the industry knowledge and experience about the workflow and information sharing flow of a business use case within the life cycle of a building project. An IDM identifies the data and information that need to be transferred from one stakeholder to another and when the transfer should occur. Specifically, the major goals of an IDM are as follows:

- Identify and describe the processes in which data sharing is required
- Identify the data producer and receiver for each data sharing scenario
- Document the specific data requirements for each data sharing scenario

The core components of an IDM include the following:

- A process map that explains the sequence of activities to be completed and the actors (stakeholders) involved in the process. Figure 2-1 shows a formal BPMN process map for a pre-construction workflow.

- ERs that specify the data entities/attributes to be transferred and the senders and recipients. Figure 2-2 shows a portion of an ER specification that clearly describes the required and optional data entities and attributes for the corresponding ERs in the process map.

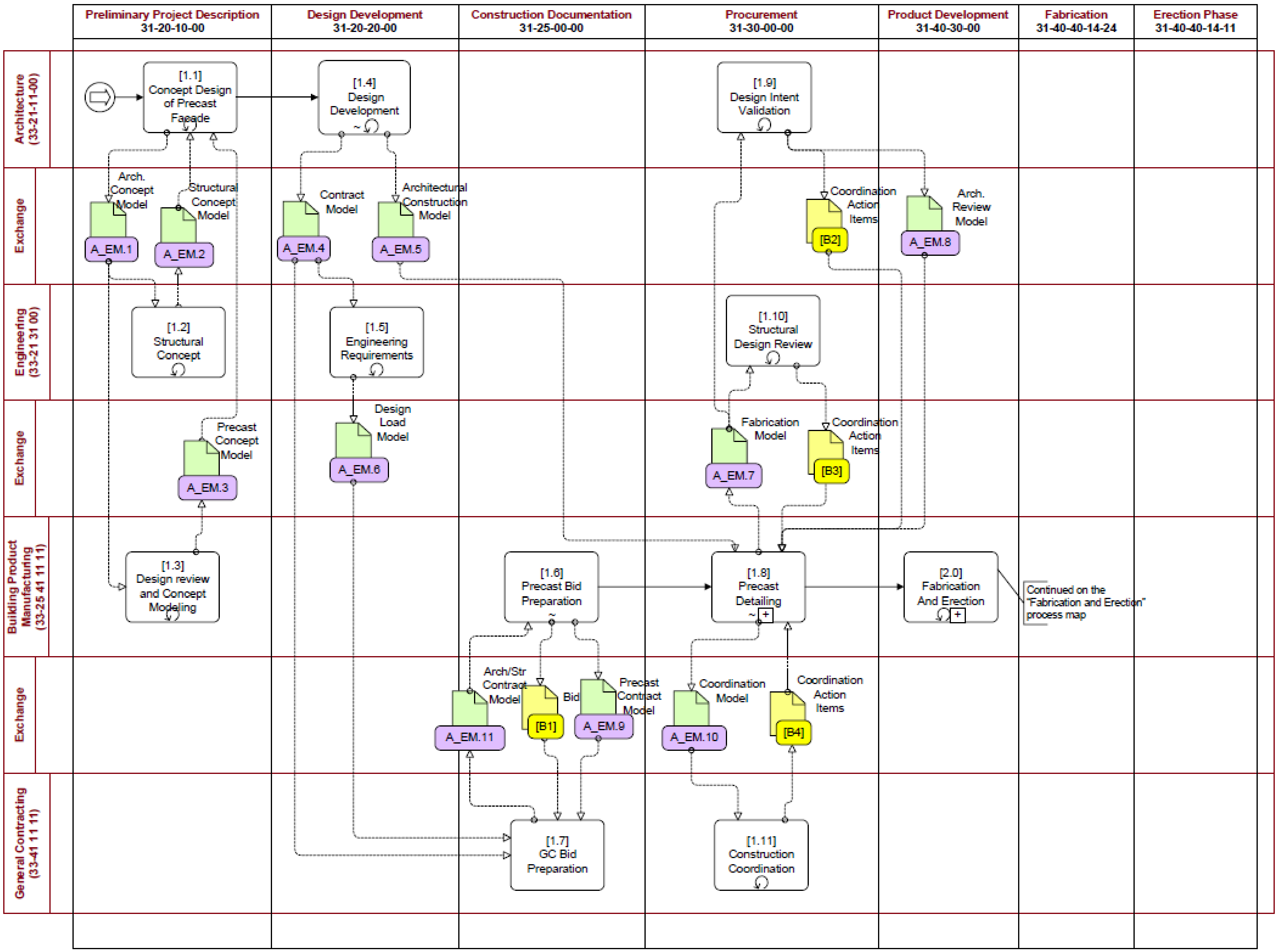

Figure 2-1. Process map of the pre-construction phase

Information Group	Information Items	Attribute Set	Attributes		Building Concept (BC_EM) A_EM.1	P_EM.1	S_EM.1	P_EM.2
Project: **Participants**	Owner, Architect of Record, Engineer of Record, General	Identity	Name, Function	Required?	O	O	O	O
		Contact Info	Addresses	Required?	O	O	O	O
			Phones, email, etc.	Required?	O	O	O	O
Project: **Site**								
	Site			Required?	O	O	O	O
		Perimeter	2D Geometry	Function?	V	V	V	V
				Accuracy?	P	P	P	P
		Location	Longitude, Latitude, Orientation	Required?	O	O	O	O
		Topography	Digital terrain model or contours	Required?	O	O	O	O
				Function?	V	V	V	V
		Assembly relations	Contains buildings...	Required?	R	R	R	R
		Meta Data	Author, Version, Date	Required?	O	O	O	O
			Approval Status, Date	Required?	O	O	O	O
Building(s)								
	Building			Required?	R	R	R	R
		Location on site	Position and orientation	Function?	F	F	F	F
				Accuracy?	P	P	P	P
		Grid geometry & control planes	Origin, directions, steps, labels	Required?	R	R	R	R
				Accuracy?	P	P	P	P
		Design constraints	Classification	Required?	O	O	O	O
			Use Occupancy	Required?	O	O	O	O
			Live Loads	Required?	O	O	O	O
			Wind Loads	Required?	O	O	O	O
			Fire Rating	Required?	O	O	O	O
			Importance Factors	Required?	O	O	O	O
			Seismic design requirements	Required?	O	O	O	O
		Structural Loads	Classification	Required?	O	O	O	O
			Use Occupancy	Required?	R	R	R	R
			Fire Rating	Required?	O	O	O	O
			Importance Factors	Required?	O	O	O	O
		Assembly relations	Located on site...	Required?	R	R	R	R
			Contains building systems...	Required?	R	R	R	R

Notes: O = optional, R = required, P = planar, C = curved

Figure 2-2. Data entities and attributes of the ERs

2.1.3. IDM Development Methodology

In order to support the formal documentation of IDMs, the buildingSMART alliance (bSa) developed a guide on IDM development methodology that has become the ISO 29481-1:2010 standard and a part of the National Building Information Modeling (BIM) standard (National Institute of Building Sciences 2007). Specifically, developing an IDM consists of the following major stages:

- **Define the scope of the IDM** in a way that clearly describes the specific use case in the life cycle of a project (e.g., creating design models, project handover, etc.) to be investigated. The project life cycle involves a huge number of business processes, from the programming to demolishing phases, and IDMs with high priority are identified and developed first.

- **Form a workgroup** that involves appropriate industry professionals who have background and experience relevant to the scope of the IDM. The members in the workgroup identify the activities, actors, and information sharing events that are needed to enable the completion of the identified business use case.

- **Develop a process map** based on the discussions of the workgroup. A process map representing the current practice or a proposed business process is developed to describe the sequence of work and the actors who perform the activities in the workflow. The process map also locates where data exchange should occur and the level of detail needed. The process map is modeled using BPMN, which can allow for visualization and the development of supporting applications. Along with the BPMN flowchart, the map is described in understandable language for the end user.

- **Create data ERs** for each of the data sharing scenarios identified in the process map. An ER consists of the following information: (1) who is requesting the information, (2) why the activity is happening, (3) the phase of the project in which the activity takes place, (4) the data (entities, objects, and properties) that are needed, (5) to whom the information is being given, (6) the resources (e.g., computer systems or equipment) used for a specific activity, and (7) inputs and outcome data. An exchange requirement is shown as a “message-driven event” in the BPMN process map.

- **Develop a software application to facilitate the implementation of IDM.** This stage aims to identify the applications that support each component of the work in the workflow and map the data identified in the ER to the entities/attributes in the software application.

2.1.4. IDM Development Status

IDM has attracted significant attention worldwide. According to a review of the existing efforts, more than 30 separate IDM projects have been developed or are in progress for various business processes within the life cycle of a building project.

The top prioritized IDMs identified by the bSa include the following:

- Perform energy analysis in the feasibility phase
- Create architectural, structural, electrical, and HVAC BIM models in the design phase
- Perform quantity take-off and cost analysis during the coordinated design and procurement stage
- Develop facility management documentation during the coordinated design and procurement stage
- Perform consistency control during the coordinated design and procurement stage

2.2. Related Research

A plethora of studies have examined various aspects of IDM. One major line of research focuses on IDM development. Nawari (2011) developed an IDM for structural design, including a process map and the information exchange requirements needed for implementation. Similarly, Nawari developed an IDM for designing and analyzing wood structures (2012a), an IDM for off-site construction (2012b), and an IDM for designing tensile structures (2014). Jallow et al. (2013) presented an information exchange table showing different groups of information exchange items and their dependencies to assist in developing IDMs for energy efficient retrofit projects. Studies on IDMs are not limited to the building sector. Obergriesser and Borrmann (2012) proposed an IDM for the geotechnical infrastructural design of bridges that included interactions among geotechnical engineers, terrestrial surveyors, transportation engineers, and structural engineers. Furthermore, with new project delivery methods such as design-build and integrated project delivery, contractors and manufacturers also influence the design process. Berard and Karlshoej (2012) proposed an IDM to incorporate construction methods and products into the bidding process for design-build projects to reduce design errors.

Information exchange is important for achieving interoperability between different parties who may use heterogeneous applications. In order to improve the effectiveness of information exchange during the project delivery process, several attempts have been made to utilize IDMs for better information management. In an attempt to leverage remote sensing technologies for bridge inspection, Sacks et al. (2016) aimed to automatically generate a bridge model by integrating point cloud data (from laser scanning technology and photogrammetry) with an expert system of bridge component classification. To ensure that the output model worked effectively, the authors deployed IDMs to define information requirements and connect integrated parts of the system with each other. In another implementation case, Karlshøj et al. (2016) applied construction operation building information exchange (COBie) to curtain walls and developed two IDMs to control information exchanges. With the same intention of improving asset management and with an additional purpose of eliminating duplicate work, Hoeber and Alsem (2016) presented a BIM-based life-cycle approach used in the Netherlands in which collaboration between project managers and asset managers is required in the beginning stages of the project. In this approach, IDMs are used as a formal contract document to define required deliverables. To evaluate the efficiency level of buildings and manage project objectives, Klobut et al. (2016) developed a key performance indicators (KPIs) framework for a research project named Design4Energy (D4E). Thanks to IDMs, specifically process maps and exchange requirements, the researchers incorporated KPI targets and their assessment processes into the early design phase, which in turn helped improve the building design process.

Despite an extensive amount of research, as discussed above, data exchange processes still rely on paper or electronic paper-based formats rather than digital data sets. The majority of studies on IDMs have been conducted for the building sector, and very little research has been undertaken for the transportation sector. Several efforts have been made by the Federal Highway Administration (FHWA) through various webinar series to provide guidance and assistance for implementing digital modeling for highway projects. However, specific guidance on managing the flow of data and information across highway project phases is lacking. Research is needed to understand the current state of the practice in digital data sharing throughout the life cycle of a transportation project and to develop guidance on data flows, data sharing requirements, and supporting software applications and techniques to allow full reuse of digital data and information for particular use scenarios.

3. CURRENT DATABASES AND SOFTWARE APPLICATIONS

3.1. Databases

The following databases are used by the Iowa DOT to archive[AMK[1] data created throughout the workflows of different sign, guardrail, culvert, pavement, and bridge assets:

- ProjectWise is used to stored data related to the project, such as MicroStation design files, tabulations, and MS Excel files.
- The Electronic Records Management System (ERMS) stores contract data and other information, such as design plan PDFs and as-built drawings.
- Oracle databases store inventory and condition data of signs, culverts, and traffic barriers with a series of related tables in the same system.
- Bid Express is a cost estimate database that helps determine the average unit price for bid items.
- The Structure Inventory and Inspection Management System (SIIMS) is the single-source location for entering and reviewing condition information for all Iowa bridges, both local and state-owned.
- The Crash Mapping Analysis Tool (CMAT) is a software program that provides convenient access to Iowa crash data through a GIS interface. Functionality in CMAT can also be found in a web-based Safety Analysis, Visualization, and Exploration Resource (SAVER) tool.
- The Pavement Management Information System (PMIS) contains various levels of data describing the pavement conditions and histories of Iowa's Interstates and primary routes.
- The Bridge Information System (BRIS) is a Microsoft Access database program that serves as an inventory of bridge projects.

These databases are summarized in Table 3-1.

Table 3-1. Databases

Databases	Assets				
	Signs	Guardrails	Culverts	Pavements	Bridges
ProjectWise	√	√	√	√	√
ERMS	√	√	√	√	√
Oracle databases	√	√	√	√	√
Bid Express	√	√	√	√	√
SIIMS				√	√
CMAT, SAVER				√	√
PMIS				√	√
BRIS					√

3.2. Software Applications and Data Format

The following software applications are used in various phases of the project life cycle, including planning, design, contracting, construction, and operation and maintenance:

- Google Earth is used to verify the features that exist on the roadways and their locations. Designers can perform measurements using Google Earth.
- Roadview serves much the same function as Google Earth, but it is a collection of street-level pictures rather than satellite images, as in Google Earth.
- SignCAD is used to design signs. Once the design is completed, it is exported to MicroStation.
- MicroStation is used to assist design processes in producing design plans. Plan production is aided by seed files for typical plan sheets and standard drawings.
- Geopak helps utilize survey data and improve design quality by applying 3D modeling technology.
- MS Excel is used to summarize design information in spreadsheet files. The Iowa DOT is developing an Oracle-based system to store the design information in the future.
- Adobe Acrobat is a software application used to view, create, and manage PDF files. Final design details are summarized in PDF files.

- The ArcGIS collector app for smartphones and tablets is used to add/update information collected in the field into an online GIS map. All data is currently stored, edited, and maintained in an Oracle Spatial Database Engine (SDE) enabled system.

- FieldManager and FieldBook are the programs that resident construction engineers (RCEs) and field inspectors, respectively, used to document activities pertaining to the contract. However, the Iowa DOT is migrating into an enterprise system called AASHTOware Project.

- DocExpress is a paperless contracting system that includes electronic signature technology. Users can submit, access, exchange, and track the contract documents during a project.

- Preliminary bridge design software includes the following:
  - Iowa DOT annual exceedance probability discharge spreadsheet
  - Iowa Bridge Backwater software

- Final bridge design software, according to Iowa DOT (2017a), includes the following:

  - Mathcad sheets used for various aspects of the American Association of State Highway and Transportation Officials (AASHTO) load and resistance factor design (LRFD) steel I-girder design: bearing stiffener, field splice, intermediate stiffener size, negative resistance, plastic moment–negative, plastic moment–positive, positive moment constructability, positive resistance, shear connectors, and shear resistance.

  - RC-Pier used for LRFD T-pier design and LRFD frame pier design

  - Spreadsheets used to determine top-of-slab elevations (CCS, CWPG, PPCB), beam line haunch elevations (CWPG, PPCB), and haunches (PPCB) for straight, constant-width bridges

  - Spreadsheets used to determine typical pier loads based on the AASHTO LRFD code for use with the RC-Pier software application

  - Spreadsheets used in the LRFD design of typical pier caps, pile footings, and steel-laminated elastomeric bearings

  - Miscellaneous programs for determining rebar lengths, designing deck drains, and preparing cost estimates

These software applications are summarized in Table 3-2.

Table 3-2. Software applications

	Assets				
Software Applications	**Signs**	**Guardrails**	**Culverts**	**Pavements**	**Bridges**
Google Earth	√	√	√	√	√
Roadview	√	√	√	√	√
SignCAD	√				
MicroStation	√	√	√	√	√
Geopak		√	√	√	√
MS Excel	√	√	√	√	√
Adobe Acrobat	√	√	√	√	√
ArcGIS collector app	√	√	√		
FieldManager	√	√	√	√	√
FieldBook	√	√	√	√	√
DocExpress	√	√	√	√	√
Bridge design software					√

4. CURRENT DATA WORKFLOWS OF SIGNS

This chapter captures the current knowledge and practice regarding the workflows and life cycles of sign asset data, from project initiation to operation and maintenance. Three PMs and one ER matrix for sign assets are included in this chapter.

4.1. Sign Construction/Reconstruction Project (PM.S.1)

4.1.1. Overview

The life-cycle workflow of a construction/reconstruction project for signs, as shown in Figure 4-1, shares common processes with a typical construction project and can be divided into the following phases (as shown in the top row of the process map): planning and programming, design, contract development, and fabrication.

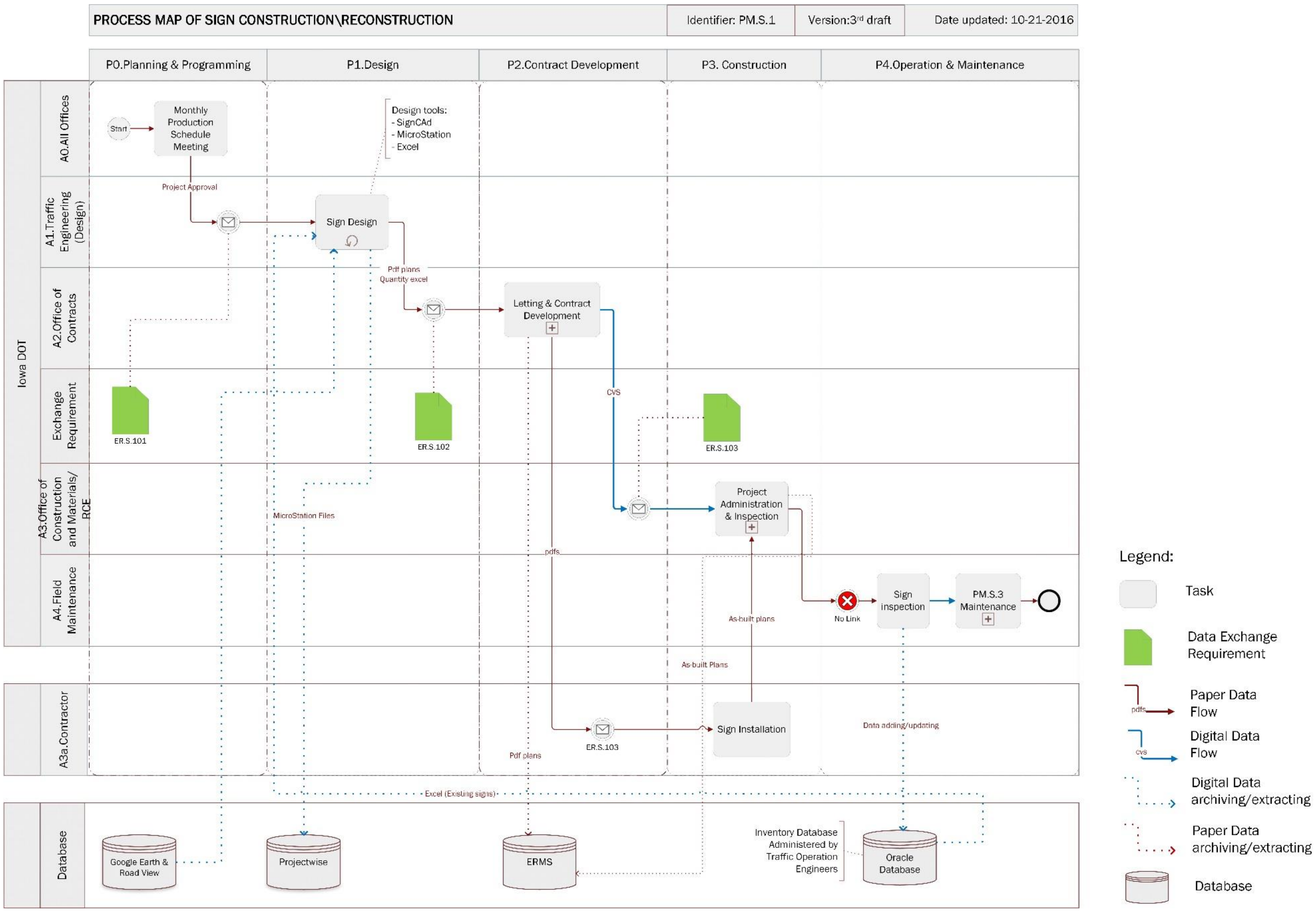

Figure 4-1. Process map of sign construction/reconstruction

Actors involved in the workflow, as presented in the left column of the process map, included a monthly production schedule meeting board, traffic engineers (design function) from the Office of Traffic and Safety, the Office of Contracts, the Office of Construction and Materials and the RCE, and the contractor.

4.1.2. Actors

4.1.2.1. Monthly Production Schedule Meeting Board

The production schedule meeting is held every month with the involvement of all relevant offices to determine new construction or reconstruction needs across different districts within the state. A new sign construction project is usually prompted by the construction of larger associated projects such as roadways.

4.1.2.2. Traffic Engineers (Design Function)

The traffic engineers in the Office of Traffic and Safety lead the design phase. The purpose of this stage is to determine the types of signs to be placed and their geometry information in accordance with federal and state manuals and specifications. Excerpts of relevant manuals used by the Iowa DOT for sign design include the Sign Inventory User's Guide, Iowa DOT Standard Specifications–Division 25 Miscellaneous Construction, Iowa DOT Standard Road Plans, and Sign Truss Standards. Designers use Google Earth or Roadview to identify the location of existing signs to make decisions on the locations of new signs. Signs are placed in MicroStation, which supports automated creation of PDF plans. An Excel file summarizing design attributes and quantity items is manually created. Designers also perform preliminary estimates for the bid items. At the end of the design phase, designers produce a set of MicroStation files, PDF plans, tabulations, and Excel files. MicroStation and Excel files are archived in ProjectWise, while PDF plans are transferred to the Office of Contracts.

4.1.2.3. Office of Contracts

The Office of Contracts loads the design quantity information received from the Office of Traffic and Safety along with unit price data into its own systems to estimate the duration and total cost of the project. When the contract is signed, all of the contract documents, including PDF plans, bid quantities and prices, and relevant specifications, are uploaded to Doc Express, which is used by the Office of Construction and Materials or the RCE to manage the project.

4.1.2.4. Office of Construction and Materials

Construction engineers inspect the project during the construction phase to ensure that the signs are installed at the correct locations, the correct materials are used, and other contracted requirements such quantity, quality, and schedule are met. As-built information is presented in PDFs and stored in the ERMS. These as-built data are mainly recycled from the design PDF plans. Other data created in this phase related to materials and costs are stored in the ERMS as well. The project-related documents, which include both as-planned and as-built data, are finally collected in the ERMS for permanent archiving.

4.1.2.5. Contractor

A contractor is hired to install the new signs. Material details and quantities need to be submitted to the Office of Construction and Materials for approval. The contractor submits as-built plans at the completion of the project.

4.1.3. Data Exchange Requirement

An ER document specifies the data to be exchanged between a certain pair of players within the workflow. The data exchange events for signs are listed below. The details of the data attributes are presented in the sign ER matrix (see Figures 4-4 through 4-6 at the end of this chapter).

- **Monthly Production Schedule Meeting Board to Traffic Engineers (ER.S.101):**
  The main deliverable of the production schedule meeting is a list of approved new construction projects for every district. The design needs and other activities (including sign-related activities) associated with all approved new construction projects are discussed during the monthly production schedule meeting. After receiving the project information, the traffic engineers are in charge of sign design.

- **Traffic Engineers to Office of Contracts (ER.S.103):**
  At the end of the design phase, sign designers send MicroStation files, PDF plans, tabulations, and Excel files to the Office of Contracts for proposal development. Sign installation requirements and specifications are included in the contract to be used by the contractor during construction. The exchanged information may include sign identifier, location, color, size, message, and type; replacement notes; sign material; post type, dimensions, and quantity; and footing.

- **Office of Contracts to Office of Construction and Materials and/or RCE/Contractor (ER.S.104):**
  When the contract is signed, PDF plans, bid quantities and prices, and relevant specifications are uploaded to Doc Express and then used by the Office of Construction and Materials or the RCE to help manage the project. These documents are also included in the contract to be used by the contractor during construction.

4.2. Sign Replacement Project (PM.S.2)

4.2.1. Overview

Funding of about $3 million per year is assigned for the monthly replacement of signs in six districts. Figure 4-2 presents the process map for a sign replacement project.

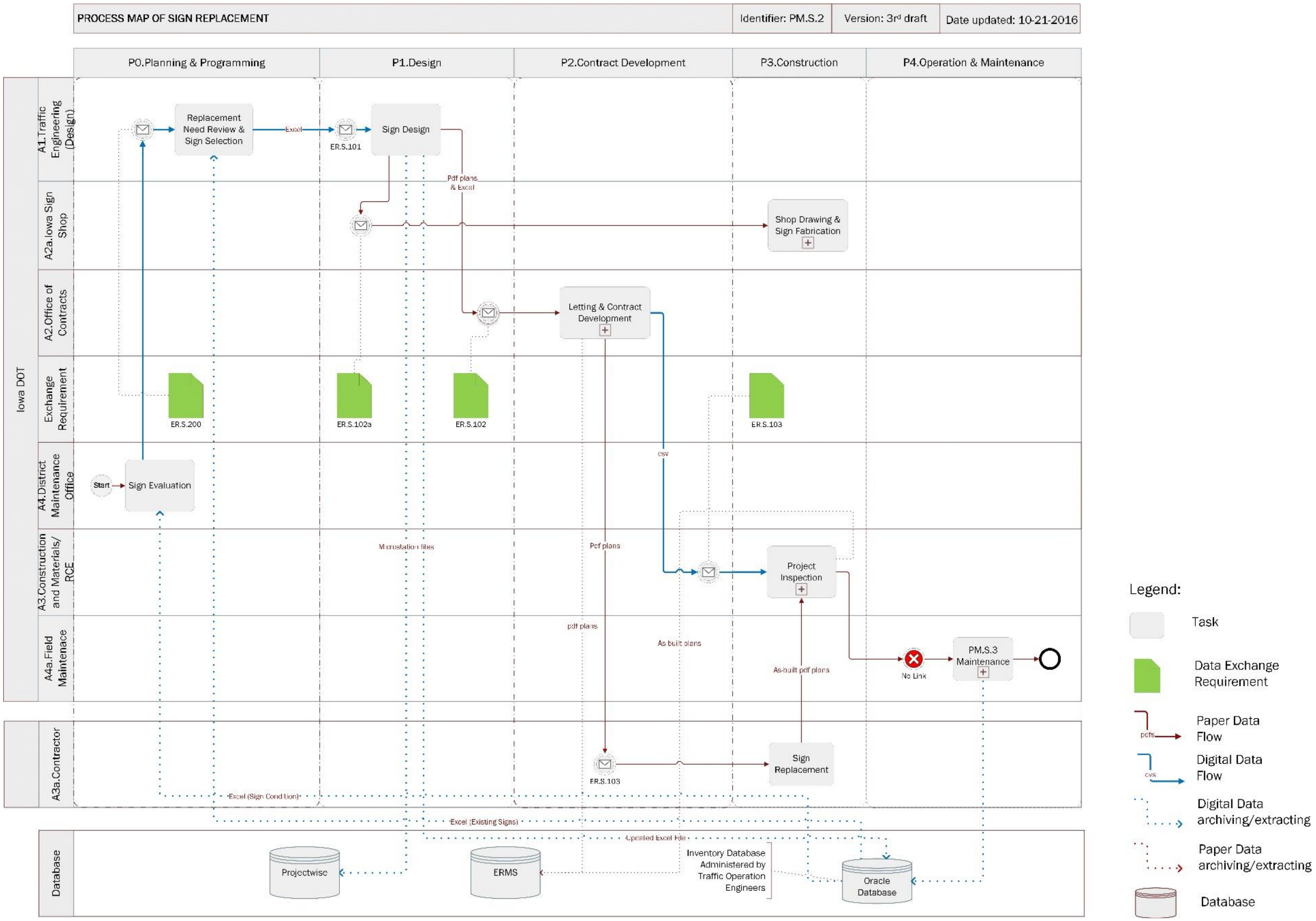

Figure 4-2. Process map of sign replacement

The sign replacement workflow can be divided into the following phases (see the top row in the process map in Figure 4-2): planning and programming, design, contract development, fabrication and installation, and operation and maintenance. Actors involved in the workflow, as presented on the left column of the process map, are the district maintenance office, traffic engineers (design function), Iowa sign shop, Office of Contracts, Office of Construction and Materials and the RCE, and the contractor.

4.2.2. Actors

4.2.2.1. District Maintenance Office

The maintenance office in each district evaluates the condition of its signs and develops a list of potential signs that need to be replaced. This list of signs is sent to the traffic engineers in the Office of Traffic and Safety for review and approval.

4.2.2.2. Traffic Engineers (Design Function)

The traffic engineers in the Office of Traffic and Safety are responsible for reviewing the sign replacement needs from the districts and making the final selections based on a holistic consideration of sign condition and available budget. This final list of selected signs, along with the corresponding inventory data exported from the Oracle database in Excel format, is sent to the designers in the Office of Traffic and Safety to update the design in accordance with the latest specifications and standards. Any changes to the existing signs are highlighted in the Excel file, which is then sent to the operation engineers in the Office of Traffic and Safety, who update the inventory data.

4.2.2.3. Iowa Sign Shop

The Iowa sign shop is responsible for fabricating the signs once the design is completed. Before the fabrication of the signs, shop drawings are developed to describe the design in detail. Shop drawing development is based on the summarized designed information and other detailed requirements specified in the attached manuals, specifications, and standards received from the Office of Traffic and Safety. These drawings need approval from the Iowa DOT before fabrication. The fabricated signs are provided to the selected contractors.

4.2.2.4. Office of Contracts

See section 4.1.2.

4.2.2.5. Office of Construction and Materials

See section 4.1.2.

4.2.2.6. Contractor

See section 4.1.2.

4.2.3. Data Exchange

The cases in which data exchange is required are listed below. The details of the data to be exchanged are presented in the sign ER matrix (see Figures 4-4 through 4-6 at the end of this chapter).

- **Designers to Iowa Sign Shop (ER.S.102):**
  The Iowa sign shop is responsible for fabricating the signs once the design is completed. Sign requirements and specifications are sent to the Iowa DOT sign shop, which develops the shop drawings in accordance with the requirements and specifications prepared by the Office of Traffic and Safety. The drawings need to be submitted to the Office of Traffic and Safety for review and approval before proceeding with fabrication.

- **Designers to the Office of Contracts (ER.S.103):**
  See section 4.1.3.

- **Office of Contracts to Office of Construction and Materials/RCE:**
  See section 4.1.3.

- **Office of Contracts to Contractors (ER.S.104):**
  See section 4.1.3.

4.3. Sign Maintenance Activity (PM.S.3)

4.3.1. Overview

Figure 4-3 presents the process map for sign maintenance.

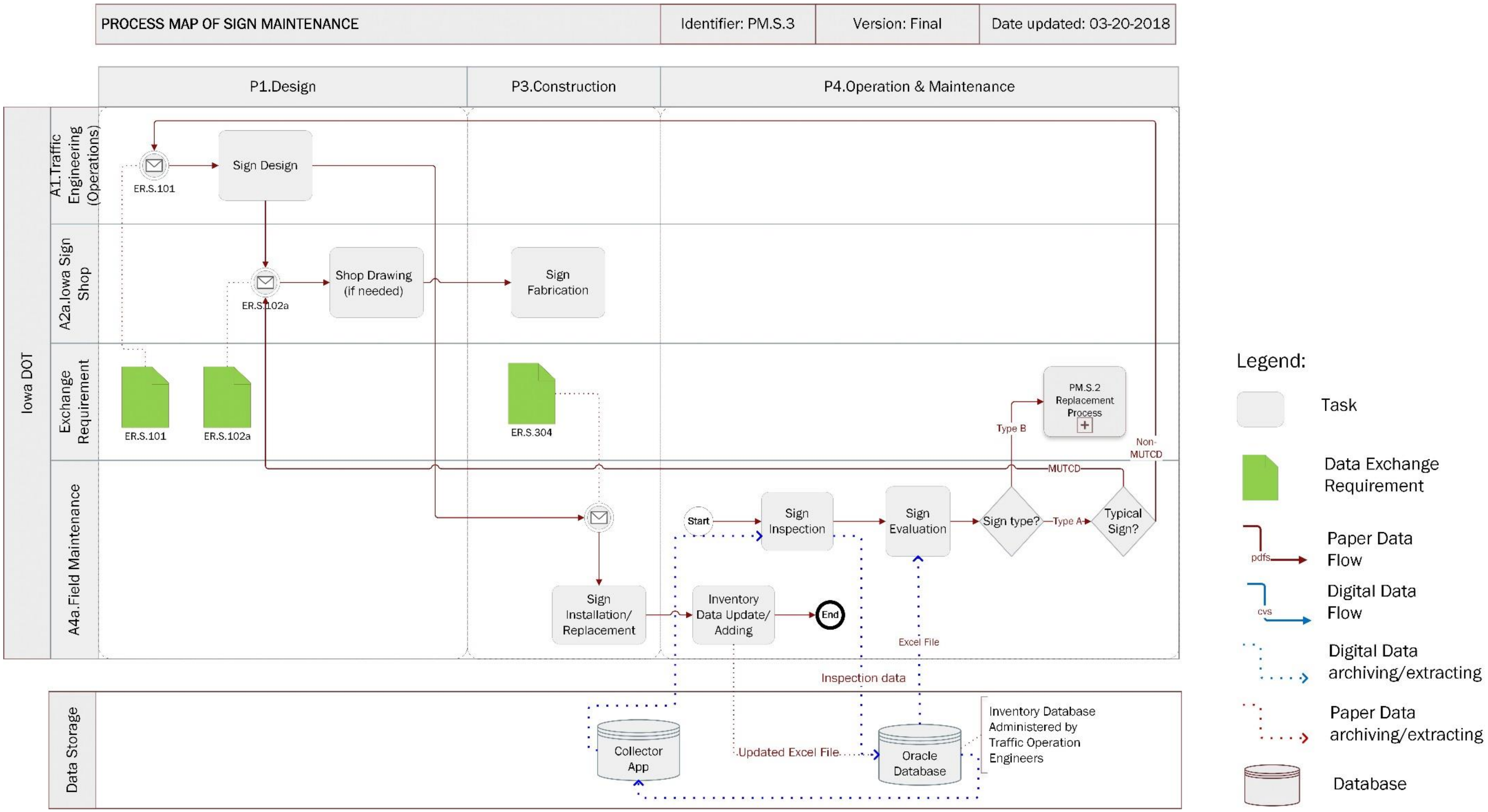

Figure 4-3. Process map of sign maintenance

Sign maintenance involves tasks from the following project phases: (P4) operation and maintenance, (P1) design, and (P3) fabrication. Actors participating in the workflow, as presented in the left column in the process map, are field maintenance staff (A4a), traffic engineers (operation function) (A1), and the Iowa sign shop (A2a).

4.3.2. Actors

4.3.2.1. Field Maintenance Staff

Field maintenance staff are responsible for most of the activities in this workflow. Their specific tasks include sign inspection, condition evaluation, and maintenance. Data collection is completed using an Esri GIS data collector application to add or update information on the conditions of existing signs. Field maintenance staff also perform some small-scale sign replacement projects where a sign has been knocked down or damaged. Depending on the size of the sign, either the local shop will do the repair, the district sign team will do the repair, or the sign will be added to the monthly sign replacement letting. For non-Manual on Uniform Traffic Control Devices (MUTCD) signs that are not specified in the sign standards, field staff need a detailed design from the designer before fabrication. Otherwise, field staff can send a fabrication order directly to the Iowa sign shop. Field maintenance staff coordinate with the traffic operation engineers to update the inventory data in the Oracle database.

4.3.2.2. Traffic Engineers

See section 4.1.2.

4.3.2.3. Iowa Sign Shop

See section 4.1.2.

4.3.3. Data Exchange

The data exchange events during the sign maintenance workflow, as shown in Figures 4-4 through 4-6, include the following:

- **Field Maintenance Staff to Traffic Engineers (ER.S.201):**
  A final list of signs to be replaced/maintained is sent to the Office of Traffic and Safety by the district maintenance office/maintenance garage. The exchanged information may include sign identifier, location, and type.

- **Designer to Iowa Sign Shop (Only for Non-MUTCD Signs) (ER.S.102):**
  See section 4.2.3.

- **Designer to Field Maintenance Staff (Only for Non-MUTCD Signs) (ER.S.105):**
  At the completion of the project, the contractor needs to submit as-built drawings and documents for the project to the Iowa DOT, which pushes the documents to the staging database. The exchanged information may include sign identifier, installation, location, color, size, message, and type; replacement notes; sign material; post type, dimensions, and quantity; and footing.

Exchange Requirement Matrix

Asset type:	Sign	Updated Date:	3/23/2018

Actor Notes

A0. Planner	A1.Designer	A2.Office of Contracts	A3. RCE	A3a.Contractor	A4. Maintenance staff

Data Exchange Notes

RD	Required, Digital
RP	Required, Paper

Data attribute group	Data attribute	Description	Comments	Created by	Updated by	Verified by	ER.S.101 to Desinger	ER.S.102a to Sign Shop	ER.S.102 to Office of Contracts	ER.S.103 to RCE or contractor	ER.S.200 to T&S	ER.S.304 to O&P
Project	Project name	Name of a project		A0			RP	RP	RD	RD		
	Project ID	Identity of a project		A0			RP	RP	RD	RD		
	Project location	Location of a project		A0			RP	RP	RD	RD		
	Start date	Expected start date of a project		A0	A2					RD		
	End date	Expected completed date of a		A0	A2					RD		
	Proposed duration	The duration of a project		A2								
	Proposed price			A2								
	Bid price			A3a		A3				RD		
	Bid duration			A3a		A3				RD		
	Quantity item			A1		A3			RD	RD		
Sign identifier	Sign ID			A3							RD	RD
	DOT stock number	Each sign is assigned a stock number		A3							RD	RD
	Iowa MUTCD	Iowa Manual on Uniform Traffic Control Devices		A3							RD	RD
	Federal MUTCD	Federal Manual on Uniform Traffic Control Devices		A3							RD	RD
	Sign Description			A3							RD	RD
	Remarks			A3						RP	RD	RD
Sign location	District	Iowa district number		A0		A3				RP	RD	
	County	County number		A0		A3				RP	RD	
	Garage	Iowa garage maintenance number		A0		A3				RP		
	Route ID	For instance, I-29		A0		A3				RP	RD	
	Milepost	Milepost of sign		A0		A3				RP	RD	
	GPS Latitude	GPS coordinate		A4							RD	
	GPS Longitude	GPS coordinate		A4							RD	
	Sign face direction	Direction of sign face (E, N, NE, etc.)		A1		A3				RP	RD	
	Travel direction	Direction of travel along a specific route		A1		A3				RP	RD	
	Side of road	Side of road where post is located, relative to direction of travel		A1		A3				RP	RD	
Sign color	Sign color	Color of sign		A1		A3		RP		RP	RD	RD
Sign size	Sign width	Width of sign		A1		A3		RP		RP	RD	RD
	Sign height	Height of sign		A1		A3		RP		RP	RD	RD
	Sign area	Area of sign		A1		A3		RP		RP	RD	RD

Figure 4-4. Sign data exchange requirement matrix (sign ER matrix), part 1

Exchange Requirement Matrix

Asset type:	Sign	Updated Date:	3/23/2018

Actor Notes

A0. Planner	A1.Designer	A2.Office of Contracts	A3. RCE	A3a.Contractor	A4. Maintenance staff

Data Exchange Notes

RD	Required, Digital
RP	Required, Paper

Data attribute group	Data attribute	Description	Comments	Created by	Updated by	Verified by	ER.S.101 to Desinger	ER.S.102a to Sign Shop	ER.S.102 to Office of Contracts	ER.S.103 to RCE or contractor	ER.S.200 to T&S	ER.S.304 to O&P
Sign message	Sign message	Message of sign		A1		A3		RP		RP	RD	RD
Sign type	Sign type	Type of sign (regulatory, warning, guide, school, rest area, construction)		A1		A3		RP		RP	RD	RD
	Subcategory	Subcategory within sign type		A1		A3		RP		RP	RD	RD
Sign material	Sheeting	Sign sheeting material (diamond grade, engineering grade, high intensity, prismatic high intensity)		A1		A3		RP		RP	RD	RD
	Blank material	Blank material of the sign (extruded aluminum, metal, wood)		A1		A3		RP		RP	RD	RD
Sign installation	Date installed			A3							RD	
Sign condition	Day condition date	Date in which most recent day condition rating was recorded		A4							RD	
	Day time rating	Most recent daytime sign rating (excellent, good, poor)		A4							RD	
	Day Retroreflectivity	Most recent day retroreflectivity reading		A4							RD	
	Night condition date	Date in which most recent night condition rating was recorded		A4							RD	
	Night time rating	Most recent nighttime sign rating (excellent, good, poor)		A4							RD	
	Night Retroreflectivity	Most recent night retroreflectivity reading		A4							RD	
	Flag Beacon	Indicates whether or not a flag or beacon is present (yes, no, both)		A4							RD	
	Comments			A4							RD	
Replacement notes	Deficiency	Noted deficiency for replacement (whether damage, design change, etc.)		A4							RD	
Post type	Post type	Type of post (e.g., wood, U-Chan.)		A1		A3		RP		RP	RD	RD
	Post type subtype	Subtype values used to drive data collection efforts utilizing the collector application		A1		A3		RP		RP	RD	RD
Post dimensions	Post size	Size of post (e.g., 4"x6')		A1		A3		RP		RP	RD	RD
	Post length	Length of post		A1		A3		RP		RP	RD	RD
Post quantity	Number of posts	Number of posts installed at an assembly location		A1		A3		RP		RP	RD	RD

Figure 4-5. Sign data exchange requirement matrix (sign ER matrix), part 2

Exchange Requirement Matrix

Asset type:	Sign	Updated Date:	3/23/2018			Data Exchange Notes	
Actor Notes						RD	Required, Digital
A0. Planner	A1.Designer	A2.Office of Contracts	A3. RCE	A3a.Contractor	A4. Maintenance staff	RP	Required, Paper

Data attribute group	Data attribute	Description	Comments	Created by	Updated by	Verified by	ER.S.101 to Desinger	ER.S.102a to Sign Shop	ER.S.102 to Office of Contracts	ER.S.103 to RCE or contractor	ER.S.200 to T&S	ER.S.304 to O&P
	Number of signs	Number of sign installed at a location		A1		A3		RP		RP	RD	RD
Post installation	Post create date	Date post was installed		A3							RD	
Post condition	Post rating	Rating of evaluator on the condition of the post (Excellent, Good, Poor)		A3							RD	
	Post status	Status of post (New post, replace post, move post, retire post, replace and move post, number of signs changed on post)		A3							RD	
	Comments			A3							RD	
Footing	Width	Width of footing		A1		A3				RP		
	Height	Height of footing		A1		A3				RP		
	Depth	Depth of footing		A1		A3				RP		
	Material	Material of footing		A1		A3				RP		

Figure 4-6. Sign data exchange requirement matrix (sign ER matrix), part 3

5. CURRENT DATA WORKFLOWS OF GUARDRAIL ASSETS

This chapter captures the current knowledge and practice regarding the workflows and life cycles of guardrail asset data, from project initiation to operation and maintenance. Two PMs and one ER matrix for guardrail assets are included in this chapter.

5.1. Guardrail New Construction/Reconstruction (PM.G.1)

5.1.1. Overview

Figure 5-1 shows the process map for a guardrail construction/reconstruction project.

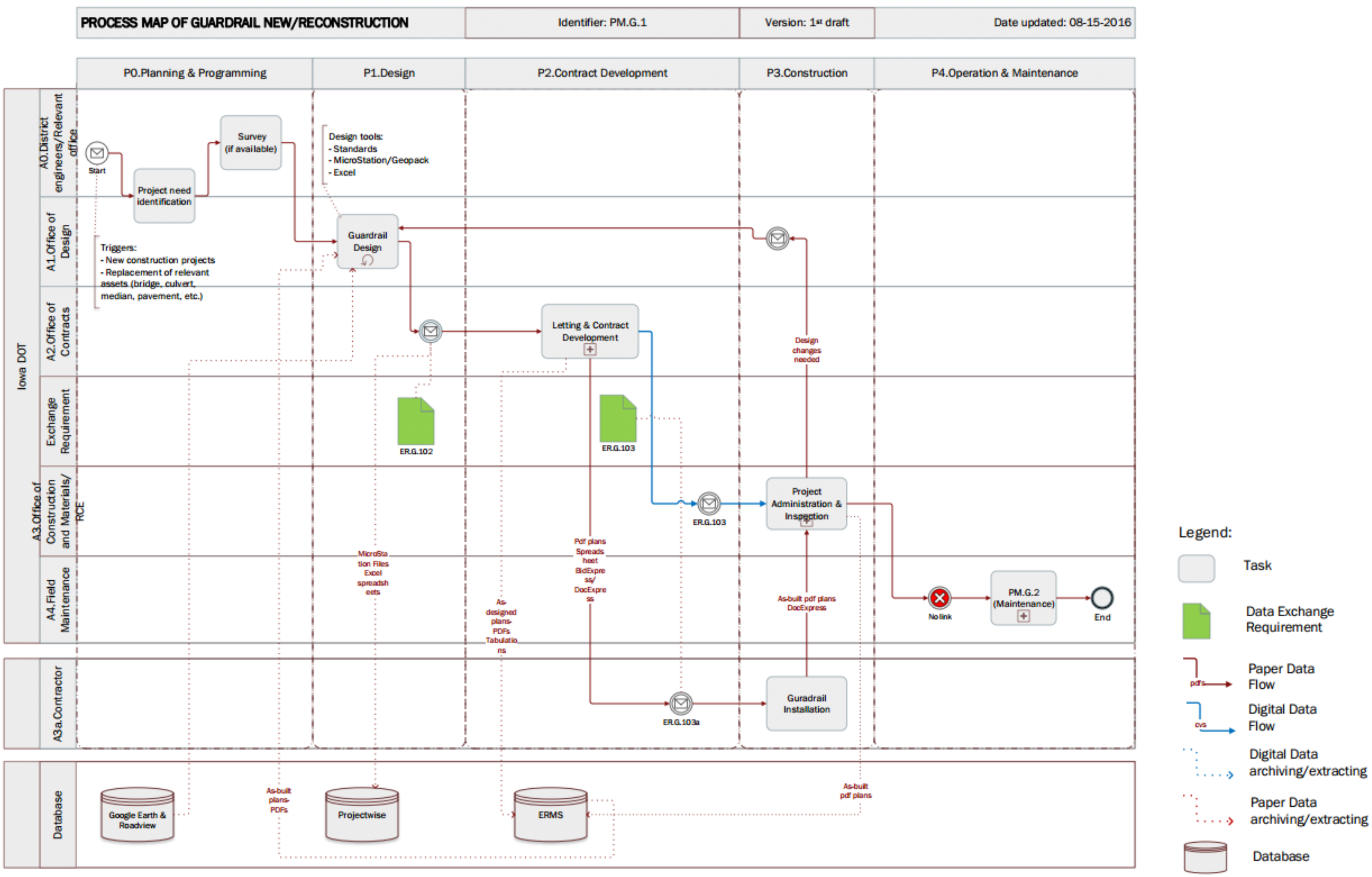

Figure 5-1. Process map of guardrail new construction/reconstruction

New guardrail construction and guardrail reconstruction are typically part of new road or bridge projects. Maintaining and updating the proper digital records throughout the entire process helps promote efficiency and prevents the recreation of the same information at every data exchange.

The process map focuses on the following main actors in the new guardrail/guardrail reconstruction process:

- District Engineers/Relevant Office
- Office of Design
- Office of Contracts
- Office of Construction and Materials/RCE
- Maintenance Shop
- Contractor

5.1.2. Actors

5.1.2.1. District Engineers/Relevant Office

In this row of the process map, a project is initiated. Through some sort of formal or informal communication, a guardrail need is identified. This usually is triggered by either new construction or replacement of existing assets (bridges, culverts, medians, pavement, etc.). Then, the district engineers or relevant offices make the appropriate attempts to obtain the required survey data. If available, the survey data is sent to the Office of Design.

5.1.2.2. Office of Design

The Office of Design's main goal is to utilize all available data for guardrail design. The designer also leverages available survey data from Google Earth, Roadview images, and as-built plan PDFs of previous projects from the ERMS. Once all necessary data are obtained, the Office of Design uses standards, MicroStation/Geopak, and Excel as its main tools to design the guardrails. After the completion of design, the Office of Design sends its completed design work to the Office of Contracts (ER.G.101). At this point, all MicroStation files and Excel spreadsheets are saved to the ProjectWise server.

5.1.2.3. Office of Contracts

Upon receiving the design package, the Office of Contracts performs the following three tasks to determine the total price of the project and who will implement the project: cost estimating, bidding, and contract development. The design information from PDF plans and Excel spreadsheets tabulations are used to quantify the work quantities, which are embedded with unit prices to estimate the total cost of the project. A qualified contractor offering the lowest price is selected. The Office of Contracts then posts all documents to DocExpress instead of mailing hard copies to the successful bidder. The contractor can use the digital signature function to sign the contract. After the contract is signed, the project information is transferred to the Office of Construction and Materials or the RCE who performs the construction inspection.

5.1.2.4. Office of Construction and Materials/RCE

The Office of Construction and Materials/RCE mainly focuses on project progress tracking. A high volume of data exchange occurs between this actor and the contractor. Most of these submissions and approvals are carried out using PDFs or paper documents. Field records are recorded in PDF format and sent through Fieldbook into the ERMS. There also may be direct contact with the Office of Design if something needs to be redesigned.

5.1.2.5. Contractor

As-built information is presented in PDF plans and stored in the ERMS. These as-built data are mainly recycled from the design PDF plans. Other data created in this phase that are related to materials and costs are stored in the ERMS as well.

5.1.2.6. Maintenance Shop

Currently, no direct communication with the maintenance shop is needed for new and reconstruction guardrail projects.

5.1.3. Data Exchange

The cases in which data exchange is required are listed below. The details of the data to be exchanged are presented in the guardrail ER matrix (see Figures 5.3 through 5.6).

- **Office of Design to Office of Contracts:**
  At the end of the design phase, designers send MicroStation files, PDF plans, tabulations, and Excel files to the Office of Contracts for proposal development. Guardrail installation requirements and specifications are included in the contract to be used by the contractor during construction. The exchanged information may include guardrail-steel beams, cable guardrails, crash cushions, temporary barrier rails, safety closures, concrete guardrails, and specifications.

- **Office of Contracts to Contractor:**
  At the end of the design phase, designers send a set of MicroStation files, PDF plans, tabulations, and Excel files of the design guardrails to the Office of Contracts for proposal development. Guardrail installation requirements and specifications are included in the contract to be used by the contractor during construction.

5.2. Guardrail Maintenance (PM.G.2)

5.2.1. Overview

Figure 5-2 shows the process map for guardrail maintenance.

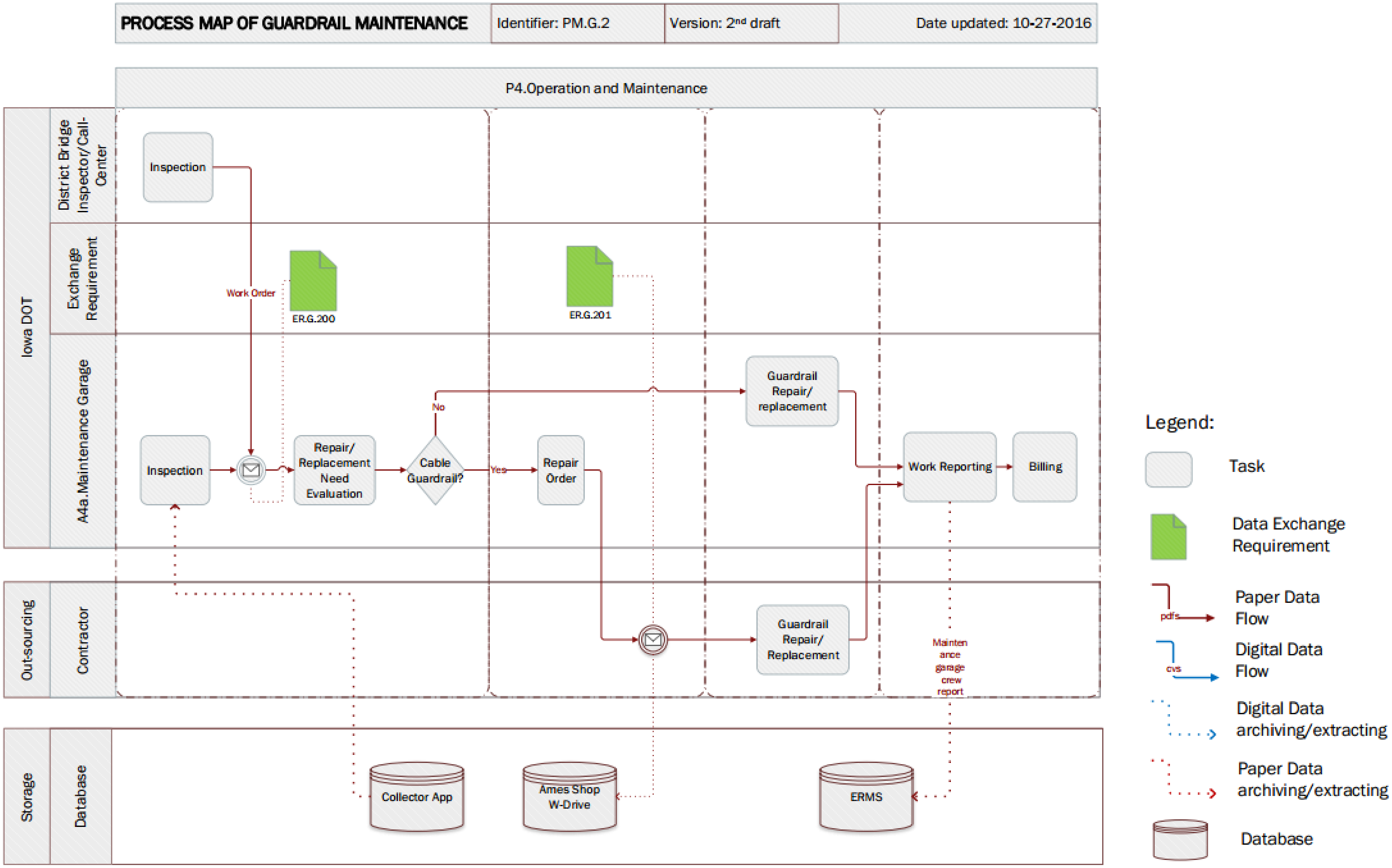

Figure 5-2. Process map of guardrail maintenance

Guardrail maintenance is important for keeping the roadway safe and protecting certain areas.

The process map focuses on the following main actors in the guardrail maintenance process:

- District Bridge Inspector/Call Center
- Maintenance Shop
- Contractor

5.2.2. Actors

5.2.2.1. District Bridge Inspector/Call Center

Through some sort of formal or informal communication, a guardrail need is identified. This usually is triggered either by an accident or simply the deterioration of an asset. The bridge inspector or call center then notifies the proper shop by phone or email with a work order that includes the information needed to make a repair.

5.2.2.2. Maintenance Shop

The maintenance shop's job is to ensure that all of the required work is completed. After receiving the work order, the shop must determine whether its staff will do the work or the work should be contracted to an outside company. If the work is to be done in-house, the shop sends a crew to do the work. The foreman fills out a paper sheet with hours and general information, which is turned in at the end of the day and saved to the ERMS. A bill is also sent to the person who caused the damage, if known. If the work is to be done by a contractor, a repair order is faxed once a week. Some of the work cost information is also stored in the Resource Management System (RMS), which is a maintenance payroll and daily log system. This information is stored by function code, which allows professionals to break down and analyze some of that costing information.

5.2.2.3. Contractor

See section 5.1.2.

5.2.3. Data Exchange

The cases in which data exchange is required are listed below. The details of the data to be exchanged are presented in the guardrail ER matrix (see Figures 5-3 through 5-5).

- **Inspector to Maintenance Shop (ER.G.200):**
  Field staff in the maintenance garages send work orders in PDF format via email to the maintenance shop if part of a certain guardrail (post, cable, etc.) is damaged. The maintenance shop needs to contact the one-call center if the repair work requires excavation.

Other supporting documents and images, if available, may be attached as well. The maintenance personnel may need to perform further inspection to evaluate the maintenance need.

- **Maintenance Shop to Contractor (ER.G.201):**
  Repair or replacement of a cable guardrail is performed by a contractor. Other types of guardrail repair, such as for W-beam guardrails, are performed by the in-house crew. A work order is sent to the contractor directly from the maintenance garage.

Exchange Requirement Matrix

Asset type:	Guardrail	Updated Date:	3/23/2018

Notes

A0. Planner	A1.Designer	A2.Office of Contracts	A3. RCE	A3a.Contractor	A4. Maintenance staff

Data Exchange Notes

RD	Required, Digital
RP	Required, Paper

Data attribute group	Data attribute	Description	Comments	Created by	Updated by	Verified by	Exchange Requirements: ER.G.102 To Office of Contracts	ER.G.103 to RCE and Contractor	ER.G.200 to Maint. Garage	ER.G.201 to Maint. Contractor
Project	Project name	Name of a project		A0			RD			
	Project ID	Identity of a project		A0			RD	RD		
	Project location	Location of a project		A0			RD	RD		
	Start date	Expected start date of a project		A0	A2		RD	RD		
	End date	Expected completed date of a project		A0	A2			RD		
	Proposed duration	The proposed duration of a project in proposal		A2						
	Proposed price	The project price given in the proposal		A2						
	Bid price	The contracted unit price		A3a		A3		RD		
	Bid duration	The contracted duration of the project		A3a		A3		RD		
	Quantity/bid item	Quantities of bid items		A1		A3	RD	RD		
Guardrail Location	Direction	Direction of traffic (WB, EB, etc.)		A1		A3		RD	RP	RP
	Side	Side of guardrail (outside, median)		A1		A3		RD	RP	RP
	Offset	Offset of guardrail to reference station?		A1		A3		RD	RP	RP
	Stations	Is the location as identified in the standard drawings as a point of reference from which all measurements are made.		A1		A3		RD	RP	RP
	Route name	The name of a route (e.g., I-35)		A1		A3		RD	RP	RP
	District			A1		A3		RD	RP	RP
	County			A1		A3		RD	RP	RP
Guardrail Length	Length	Lengths include several things. It includes the overall layout length of the installation and the length of the individual bid items for the rail installation.		A1		A3		RD		RP
Guardrail Type	Type	(e.g., steel beam, concrete, crash cushion)		A1		A3		RD		RP
	Subtype	Subcateory within a guardrail type. For example, for temporary guardrail, you must select either BA-400 or BA-401.		A1		A3		RD		RP
	Grading	Grading is the detailed layout of the grading required for each installation of rail to function properly.		A1		A3		RD		

Figure 5-3. Guardrail data exchange requirement (guardrail ER matrix), part 1

Exchange Requirement Matrix

Asset type:	Guardrail	Updated Date:	3/23/2018			Data Exchange Notes	
Notes						RD	Required, Digital
A0. Planner	A1.Designer	A2.Office of Contracts	A3. RCE	A3a.Contractor	A4. Maintenance staff	RP	Required, Paper

Data attribute group	Data attribute	Description	Comments	Created by	Updated by	Verified by	Exchange Requirements			
							ER.G.102 To Office of Contracts	ER.G.103 to RCE and Contractor	ER.G.200 to Maint. Garage	ER.G.201 to Maint. Contractor
Guardrail - Steel Beam	Long-span system -location	Is the location as identified in the standard drawings as a point of reference from which all measurements are made.		A1		A3		RD		
	Long-span system - type	Defines the length of the post gap for the installation for example a type I installation allows a post gap of no greater than 10 feet.		A1		A3		RD		
	Delineators-type	Is the type of delineator required by Road Standard SI-211. This varies depending on the shoulder and bridge width.		A1		A3		RD		
	Object marker –type	Is the type of object marker required by Road Standard SI-211. This varies depending on the shoulder and bridge width.		A1		A3		RD		
	Bolted end anchor type	This defines the end anchorage used when connecting the steel beam rail to a concrete barrier or wall. See Standard BA-202 as an example		A1		A3		RD		
	Post adapter	Defines what type of post adapter to use when connecting posts to a concrete surface. See Standard BA-210.		A1		A3		RD		
	Steel Beam Type	This defines if the rail is W-beam or Thrie-beam		A1		A3		RD		
	Barrier transition section type	Is the count of the number of transitions sections to concrete rail. See BA-201 for details		A1		A3		RD		
	End terminal type	Defines which end terminal was selected: BA-205, BA-206, LS-625, LS-626		A1		A3		RD		
Cable Guardrail	Dimensions- approach	See tab 108-9A and standard BA-351		A1		A3		RD		
	Obstacle	See tab 108-9A and standard BA-351		A1		A3		RD		
	Trailing	See tab 108-9A and standard BA-351		A1		A3		RD		
	Protection length	See tab 108-9A and standard BA-351		A1		A3		RD		
	End anchor No	See tab 108-9A and standard BA-351		A1		A3		RD		
	Obstacle width	Width of the obstacle being protected		A1		A3		RD		
	Temporary	Boolean value, yes or no		A1		A3		RD		

Figure 5-4. Guardrail data exchange requirement (guardrail ER matrix), part 2

Exchange Requirement Matrix

Asset type:	Guardrail	Updated Date:	3/23/2018

Notes

A0. Planner	A1.Designer	A2.Office of Contracts	A3. RCE	A3a.Contractor	A4. Maintenance staff

Data Exchange Notes

RD	Required, Digital
RP	Required, Paper

Data attribute group	Data attribute	Description	Comments	Created by	Updated by	Verified by	Exchange Requirements			
							ER.G.102 To Office of Contracts	ER.G.103 to RCE and Contractor	ER.G.200 to Maint. Garage	ER.G.201 to Maint. Contractor
Crash Cushion	Sand barrel – V length	See standard road plan BA-500		A1		A3		RD		
	Sand barrel – W length	See standard road plan BA-500		A1		A3		RD		
	Sand barrel – X length	See standard road plan BA-500		A1		A3		RD		
	Sand barrel – Y length	See standard road plan BA-500		A1		A3		RD		
	San barrel – Z length	See standard road plan BA-500		A1		A3		RD		
	Excavation volume	In cubic yard		A1		A3		RD		
	Embankment volume	In cubic yard		A1		A3		RD		
	No. spare parts kit	How many spare parts kits would the maintenance shop like		A1		A3		RD		
Temporary Barrier Rail	Start station	Beginning Station for placement of temporary barrier rail.		A1		A3		RD		
	End station	End Station for placement of temporary barrier rail.		A1		A3		RD		
	Anchored	Yes or no		A1		A3		RD		
Concrete Barrier	**Standard Road Plan Code**	Provides reference to standard road plan which contains design information		A1				RD		
	Expansion Joints	Provides location and side of joint if joint is required		A1		A3		RD		
	Transition Section	Provides number of BA-105 transition sections		A1		A3		RD		
	End Section	Provides number of BA-107 end sections		A1		A3		RD		
	Reinforced Paved Shoulder	Indicates if shoulder needs to be reinforced per BA-106		A1		A3		RD		
	Expansion Joints	Provides location and side of joint if joint is required		A1		A3		RD		
Repair history	Bridge number	(e.g., 8518.7035)		A4					RP	RP
	Location code	(e.g., 2.1 miles north of SR E29)		A4					RP	RP
	Function code	(e.g.,692)		A4					RP	RP
	Repair code	(e.g., 559)		A4					RP	RP
	Repair type	(e.g., corrective)		A4					RP	RP
	Repair description			A4					RP	RP
	Inspection recommendation			A4					RP	
	Repair instruction			A4					RP	RP
	No. post replaced	Estimated number of posts to be replaced		A4						RP

Figure 5-5. Guardrail data exchange requirement (guardrail ER matrix), part 3

6. CURRENT DATA WORKFLOWS OF CULVERT ASSETS

This chapter captures the current knowledge and practice regarding the workflows and life cycles of culvert asset data, from project initiation to operation and maintenance. Two PMs and one ER matrix for culvert assets are included in this chapter.

6.1. Culvert New Construction/Reconstruction (PM.C.1)

6.1.1. Overview

Figure 6-1 shows the process map for a culvert construction/reconstruction project.

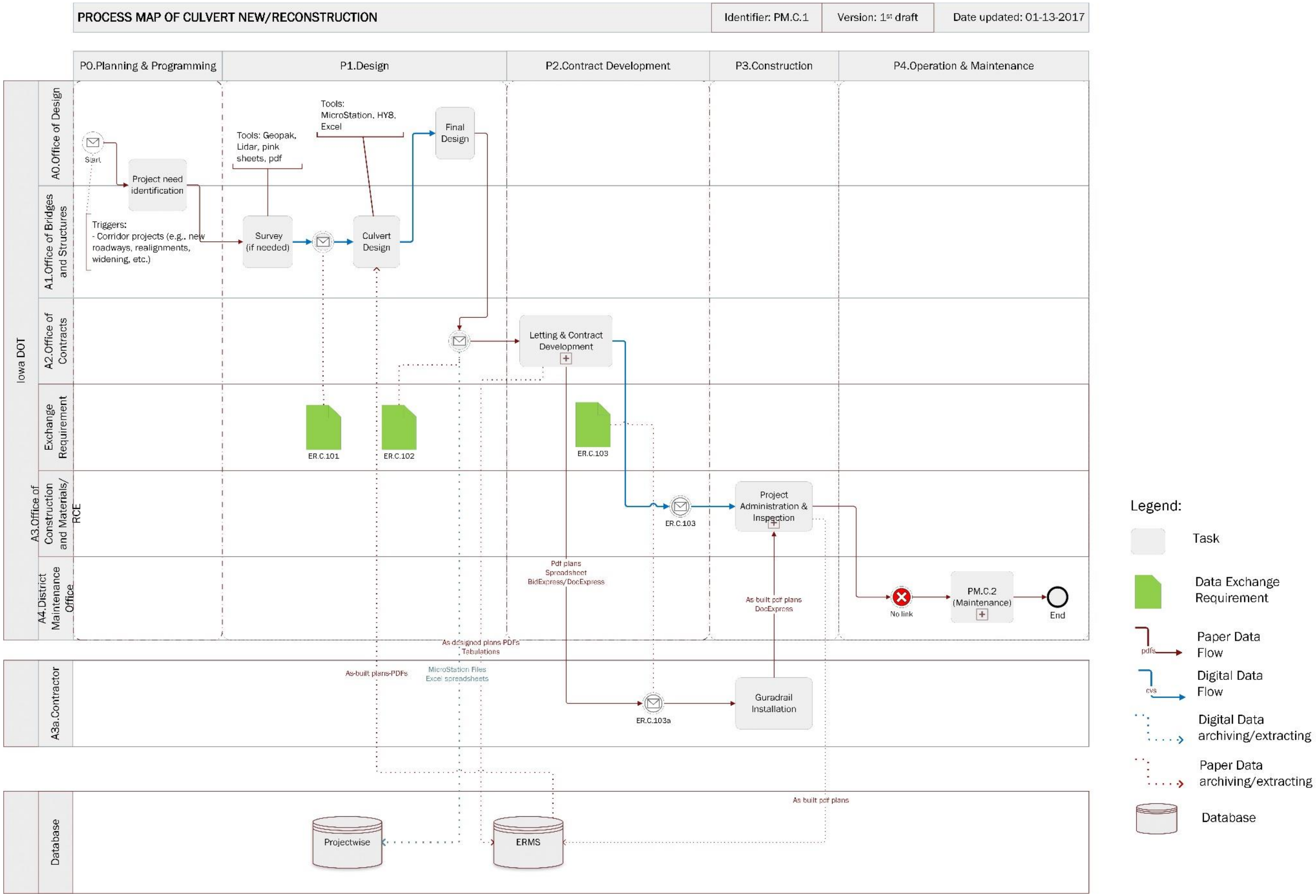

Figure 6-1. Process map of culvert new construction/reconstruction

The workflow can be divided into the following phases: planning and programming, design, contract development, construction, and operation and maintenance. Actors involved in the workflow, as presented in the left column of the process map, are Office of Design, Office of Bridges and Structures, Office of Contracts, Office of Construction and Materials and the RCE, and the contractor.

6.1.2. Actors

6.1.2.1. Office of Design

The process is similar to the process for guardrail design (see section 5.1.2). However, the Office of Design also needs a hydraulics design from the Office of Bridges and Structures to develop final plans.

6.1.2.2. Office of Bridges and Structures

The hydraulics team in the Office of Bridges and Structures uses cross-section information (from the Office and Design) and survey data to develop a hydraulic design, which includes flow lines and a schedule length spreadsheet in an Excel file.

6.1.2.3. Office of Contracts

See section 5.1.2.

6.1.2.4. Office of Construction and Materials/RCE

See section 5.1.2.

6.1.2.5. Contractor

See section 5.1.2.

6.1.3. Data Exchange Requirement

The cases in which data exchange is required are listed below. The details of the data attributes are presented in the ER matrix (shown in Figures 6-3 and 6-4 at the end of this chapter).

- **Office of Design to Office of Bridges and Structures (ER.C.101):**
  The Office of Design develops cross-sections of culverts. After that, the office sends relevant information to the hydraulics team in the Office of Bridges and Structures to develop a hydraulic design. The exchanged information may include project name, identification, and location; drainage area; kind of pipe; pipe size, and length.

- **Designers to Office of Contracts (ER.C.102):**
  After the completion of the design, the Office of Design sends the final design plans to the

Office of Contracts for letting. The official plans are in PDF format. However, digital files, such as MicroStation files and Excel spreadsheets, are also sent for reference. The exchanged information may include general design information, culvert design details, and backfill requirements.

- **Office of Contracts to Contractor (ER.C.103):**
  When a contractor is selected, the Office of Contracts then posts all documents to DocExpress and grants access to the contractor. All PDF design plans and digital files received from the Office of Design are included.

6.2. Culvert Maintenance (PM.C.2)

6.2.1. Overview

Figure 6-2 shows the process map for culvert maintenance.

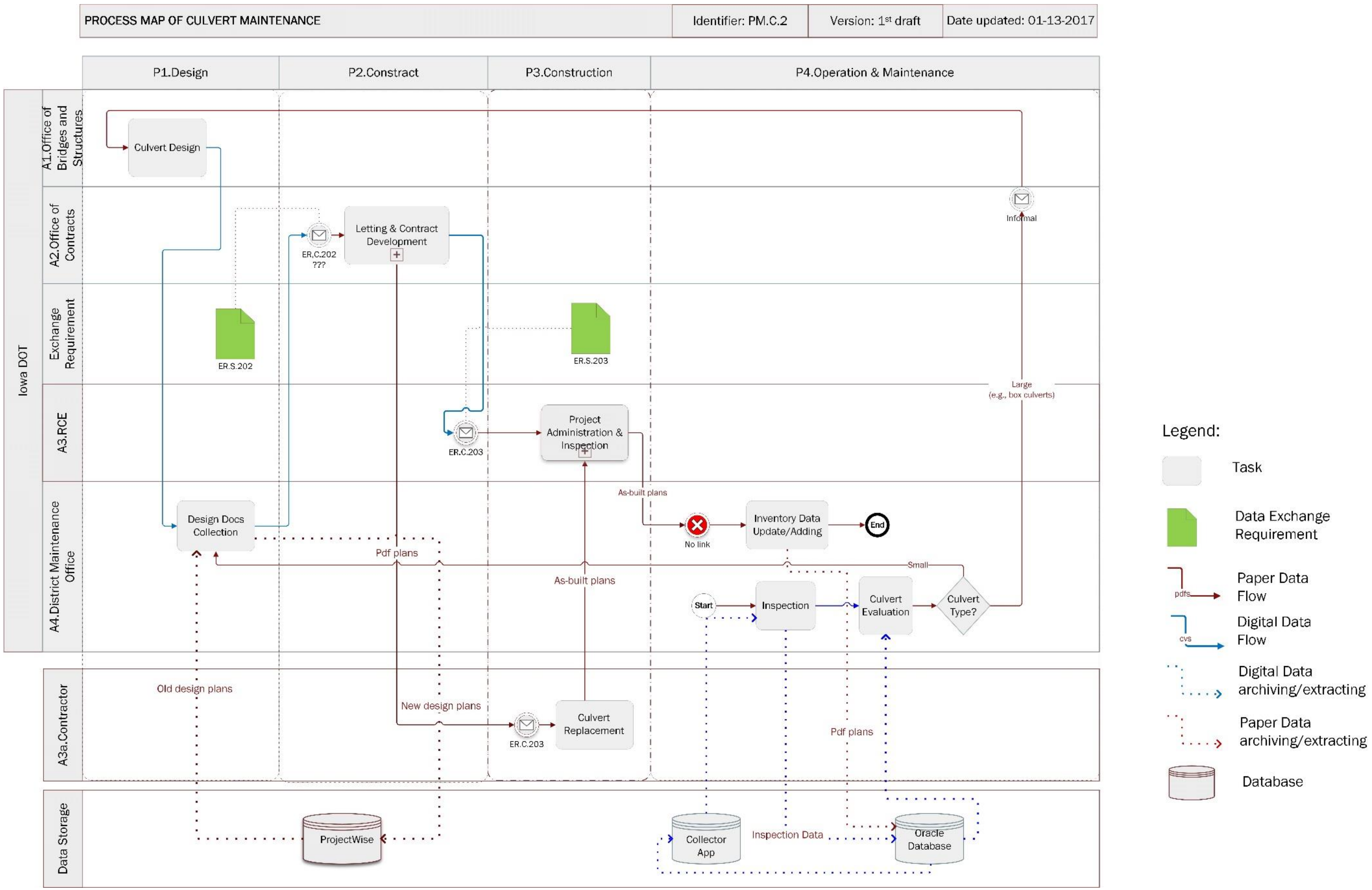

Figure 6-2. Process map of culvert maintenance

The workflow can be divided into the following phases: design, contract development, construction, and operation and maintenance. Actors involved in the workflow, as presented in the left column of the process map, are Office of Bridges and Structures, Office of Contracts, Office of Construction and Materials and the RCE, field maintenance staff, and the contractor.

6.2.2. Actors

6.2.2.1. Field Maintenance Staff

Field maintenance staff are responsible for culvert inspection and evaluation. If a culvert is damaged and replacement is needed, the relevant information is transferred to the Office of Contracts for letting. The design plans for letting could come from the Office of Bridges and Structures if the damaged culvert is large (e.g., a box culvert).

6.2.2.2. Office of Bridges and Structures

The Office of Bridges and Structures provides design plans for letting, if needed.

6.2.2.3. Office of Contracts

See section 5.1.2.

6.2.2.4. Office of Construction and Materials/RCE

See section 5.1.2.

6.2.2.5. Contractor

See section 5.1.2.

6.2.3. Data Exchange Requirement

The cases in which data exchange is required are listed below. The details of the data attributes are presented in the ER matrix (see Figures 6-3 and 6-4).

- **Field Maintenance Staff to Office of Contracts (ER.C.202):**
  Maintenance staff send the design plans to the Office of Contracts for letting. The official plans are in PDF format. The exchanged information may include general design information, culvert design details, and backfill requirements.

- O**ffice of Contracts to Contractors (ER.C.203):**
  See section 6.1.3.

Exchange Requirement Matrix

Asset type:	Culvert	Updated Date:	3/23/2018

Actor Notes

A0. Planner	A1.Designer	A2.Office of Contracts	A3. RCE	A3a.Contractor	A4. Maintenance staff

Data Exchange Notes

RD	Required, Digital
RP	Required, Paper

Data attribute group	Data attribute	Description	Comments	Created by	Updated by	Verified by	ER.C.101 to Desinger	ER.C.102 to Office of Contracts	ER.C.103 to RCE	ER.C.103a to Contractor	ER.C.104 to O&P	ER.C.204 to Dist. Mnt. Office
Project	Project name	Name of a project		A0			RD	RD	RD	RD		
	Project ID	Identity of a project		A0			RD	RD	RD	RD		
	Project location	Location of a project		A0			RD	RD	RD	RD		
	Start date	Expected start date of a project		A0	A2				RD	RD		
	End date	Expected completed date of a		A0	A2				RD	RD		
	Proposed duration	The duration of a project		A2								
	Proposed price			A2								
	Bid price			A3a		A3			RD	RD		
	Bid duration			A3a		A3			RD	RD		
	Quantity item			A1		A3			RD	RD		
Culvert design details	Drainage area			A1			RD			RP		
	Location	Station of the culvert		A1			RD			RP		
	Type	existing or new		A1			RD			RP		
	Size	Diameter or equivalent diameter (in inch)		A1			RD			RP		
	Kind of pipe	Pipe category (e.g., corrugated metal pipe, reinforced concrete pipe)		A1			RD			RP		
	Length	Length of new culvert (in LF)		A1			RD			RP		
	Bedding class			A1						RP		
	Design cover	Thickness of cover layer (in FT)		A1						RP		
	Camber	The dimension line between inlet and outlet elevation (in ft)		A1						RP		
	In apron No.	Number of apron guards at inlet		A1						RP		
	Out apron No.	Number of apron guards at outlet		A1						RP		
	Elbow No.	Number of elbows		A1						RP		
	Diaphragm No.	Number of diaphragms		A1						RP		
	Tee section No.	Number of tees		A1						RP		
	Reducer No.	Number of reducers		A1						RP		
	Type C connection type	Type of type 'C' connection		A1						RP		
	Type C connection No.	Number of type 'C' connections (e.g., C-1, C-2)		A1						RP		
	Connected pipe joint type	Type of connected pipe joints (Type 1, Type 2, Type 3)		A1						RP		

Figure 6-3. Culvert data exchange requirement (culvert ER matrix), part 1

Exchange Requirement Matrix

Asset type:	Culvert	Updated Date:	3/23/2018

Actor Notes

A0. Planner	A1.Designer	A2.Office of Contracts	A3. RCE	A3a.Contractor	A4. Maintenance staff

Data Exchange Notes

RD	Required, Digital
RP	Required, Paper

Data attribute group	Data attribute	Description	Comments	Created by	Updated by	Verified by	ER.C.101 to Desinger	ER.C.102 to Office of Contracts	ER.C.103 to RCE	ER.C.103a to Contractor	ER.C.104 to O&P	ER.C.204 to Dist. Mnt. Office
	Perforated subdrain	in ft		A1						RP		
	Left flow line elevation	Elevation of flow line at the left point		A1						RP		
	Right flow line elevation	Elevation of flow line at the right point		A1						RP		
	Dimensions (left and right)	?		A1						RP		
	Skew ahead degree (Left and right)	?		A1						RP		
	Dike side	Left, right, middle		A1						RP		
	Dike location	Station of dike		A1						RP		
	Dike top elevation	Top elevation of dike		A1						RP		
	Dike type			A1						RP		
Backfill	Class 20 volume	in CY		A1						RP		
	Flowable mortar			A1						RP		
	Floodable backfill	in CY		A1						RP		
	Porous backfill			A1						RP		
	Flooded backfill			A1						RP		
Culvert installation	constructed date	Date post was installed		A3								
Culvert condition	condition rating			A4			RD					
				A4								
				A4								

Figure 6-4. Culvert data exchange requirement (culvert ER matrix), part 2

7. CURRENT DATA WORKFLOWS OF PAVEMENT ASSETS

This chapter captures the current knowledge and practice regarding the workflows and life cycles of pavement asset data, from project initiation to operation and maintenance. Four PMs and one ER matrix for pavement assets are included in this chapter.

7.1. New Pavement Construction Project (PM.P.1)

7.1.1. Overview

The workflow of a new pavement construction project shares common processes with a typical construction project and can be divided into the following phases (see the top row in the process map in Figure 7-1): planning and programming, design, contract development, construction, and operation and maintenance.

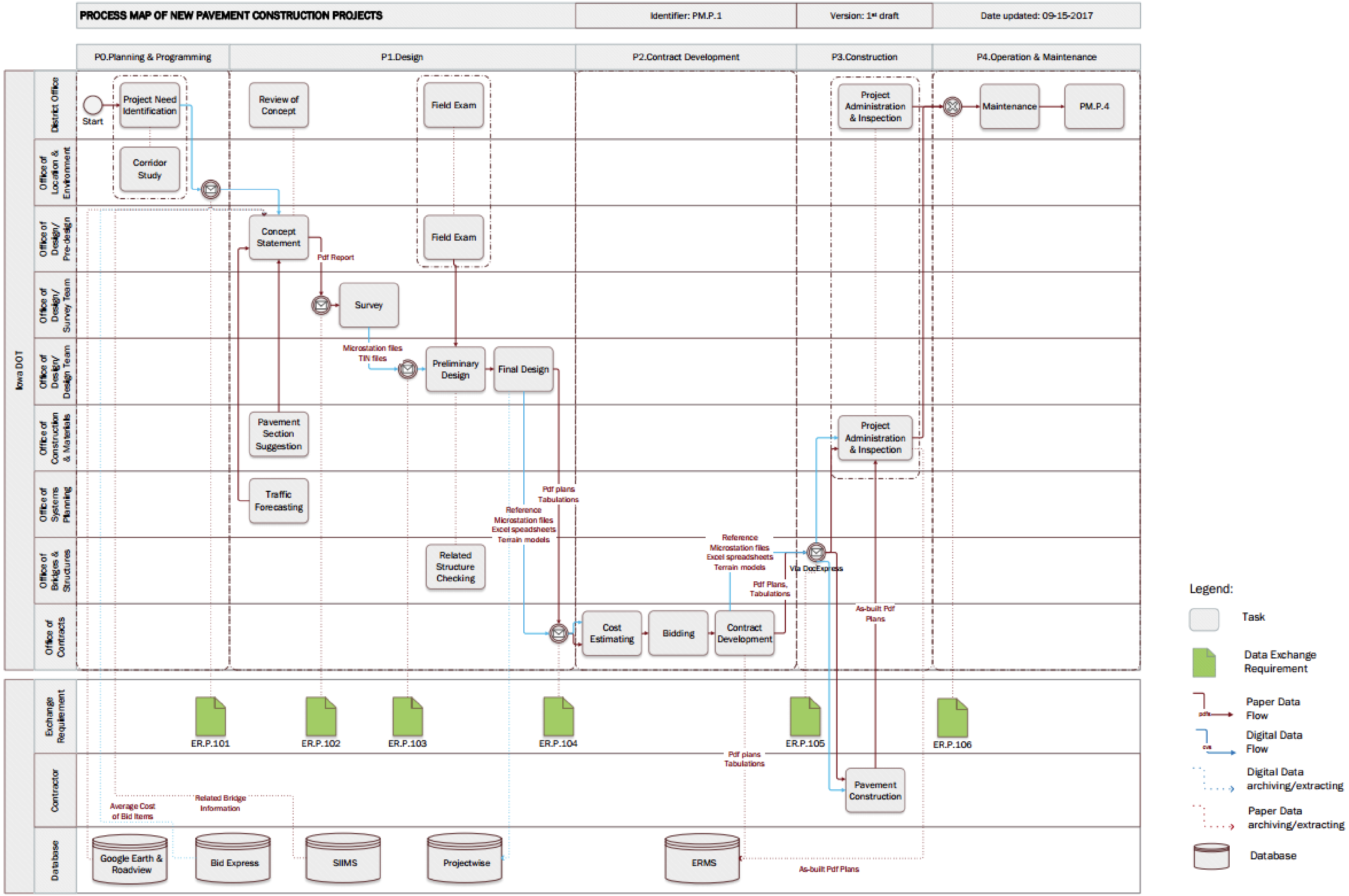

Figure 7-1. Process map of new pavement construction projects

Actors involved in the workflow, as presented in the left column of the process map, are the district office, Office of Location and Environment, Office of Design, Office of Construction and Materials, Office of Systems Planning, Office of Bridges and Structures, Office of Contracts, and the contractor.

7.1.2. Actors

7.1.2.1. District Offices

A district office includes administrative and engineering staff, field engineers, resident construction engineers, materials staff, and district maintenance staff.

In the planning phase, the district office is the entity that initiates a new project. Once the project need is identified, the district office requests that the Office of Location and Environment develop a corridor study before transferring the project to the Iowa DOT Office of Design to develop a design concept.

In addition, the district office also has important roles in several other phases, i.e., design (review and approval of the design concept and participation in the field examination), construction (project administration and inspection by resident construction engineers), and maintenance (operation and maintenance by district maintenance staff).

7.1.2.2. Office of Location and Environment

After a request from the district office, the Office of Location and Environment evaluates multiple corridor locations to identify one that provides the best transportation performance when connecting with the existing system and that can minimize potential impacts to the human and natural environments.

7.1.2.3. Office of Design

In order to develop the design concept, the pre-design/field examination team of the Office of Design examines the corridor study report from the Office of Location and Environment and leverages various data and resources, including Google Earth and RoadView images, the average cost of bid items from Bid Express, traffic forecast data from the Office of Systems Planning, information on related bridges and structures within project limits from SIIMS, and pavement section suggestions from the Office of Construction and Materials. After the draft concept is developed, it is sent to the district office for a two-week review. Based on the feedback from the district, the draft is adjusted to formulate the final concept.

Once the concept is approved and the project is funded, the preliminary survey team of the Office of Design conducts a field survey to obtain survey information for the development of the design plan. Preliminary design begins once the survey information is obtained. A field examination conducted during the preliminary design period includes representatives from the Office of Design and the district office. During the trip, the field examination engineer takes notes on the existing condition and important constraints, which will be used for subsequent design decisions. Once the field examination is completed, any necessary changes are then incorporated into the preliminary design. If other bridges or structures are involved in the project, the preliminary plans will be sent to the Office of Bridges and Structures to check coordination.

Based on the final concept design and preliminary design, designers use standard drawings, MicroStation/Geopak, and Excel as their main tools to develop the final design. After the design is finished, the Office of Design sends its completed design work to the Office of Contracts. At this point, all MicroStation files and Excel spreadsheets are saved to the ProjectWise server.

7.1.2.4. Office of Systems Planning

The Office of Design sends an official request via an email attachment asking the Office of Systems Planning to estimate traffic for the next 20-year period. The information is returned to the Office of Design through email. Copies of the traffic estimate are also sent to other offices, including the Office of Construction and Materials.

7.1.2.5. Office of Construction and Materials and District Office/RCE

Following a request by the Office of Design, the pavement engineer of the Office of Construction and Materials leverages traffic forecast data from the Office of Systems Planning as well as other condition data to develop a pavement structure design. This information is then incorporated into the design concept by the Office of Design.

During the construction phase, the Office of Construction and Materials provides guidance to the RCE to ensure that the project complies with the current specifications, policies, and procedures (Iowa DOT 2015b). Project engineers or the RCE have authority to manage construction contracts and are responsible for the general supervision of the work. The main work concerns are specification compliance and project completion.

FieldBook is a program that field inspectors and the RCE use to create inspector daily reports (IDRs) that record all activities pertaining to the contract. IDRs are then exported to FieldManager, which is used by the RCE to administer the contracts. Unlike FieldBook, FieldManager allows users to create daily diaries, contract modifications, stockpiles, and estimates.

There is considerable data transfer back and forth between the RCE, field inspectors, and the contractor. Most of these submissions and approvals are done in a paper-based format, whether as PDFs or actual paper documents. DocExpress is used to store contract-related documents. The contractor uses this system to submit documents such as change orders and schedules. Some other documents generated in FieldManager are also stored in DocExpress. The ERMS is a final permanent place to store project-related documents; ERMS staff manually transfer required documents from DocExpress to ERMS. Iowa DOT has signed the final contract with Info Tech to migrate all the data in Fieldbook and FieldManager into an enterprise system called AASHTOware Project.

7.1.2.6. Office of Bridges and Structures

Although plans for pavement work are prepared by the Office of Design, the plans must be coordinated with any other related bridges and structures within the project limits. Therefore, the preliminary design plans should be checked by the Office of Bridges and Structures before the final design is developed.

7.1.2.7. Office of Contracts

See section 5.1.2.

7.1.2.8. Contractor

See section 5.1.2.

7.1.3. Data Exchange

The cases in which data exchange is required are listed below. The details of the data attributes are presented in the ER matrix (see Figures 7-5 through 7-8 at the end of this chapter).

- **District Office to Office of Design/Pre-design Team (ER.P.101):**
  For a new pavement construction project, the district office and the Office of Location and Environment initiate the project and determine the most appropriate location for the project. After that, the district office sends relevant information to the pre-design team of the Office of Design to develop a concept design. The exchanged information may include project name, project identification, project location, and the expected start and completion dates of the project.

- **Office of Design/Pre-design Team to Office of Design/Survey Team and Design Team (ER.P.102):**
  After the final concept is approved, it is sent by email as a PDF to the survey team and design team of the Office of Design and other offices. Deliverables for the concept include project data, pavement history, existing conditions and causes of distress, safety considerations, bridge information and updates, crash history, recommended alternate, estimated cost, detour plan, recommendations, special considerations, and funds programmed.

- **Office of Design/Survey Team to Office of Design/Design Team (ER.P.103):**
  For each project, the survey team develops a survey map of all topographic features and goes out to obtain survey information. The team uses global positioning equipment to collect features in real time. After that, the team hand-picks the point clouds to map the features using mapping software to create a 3D model. The output of the survey team is a terrain model in MicroStation and triangular irregular networks (TIN) format. When the survey is done, the survey team places the survey data in ProjectWise and informs the other teams and offices. Designers use TIN files to load topographic features for developing design plans.

- **Designers to Office of Contracts (ER.P.104):**
  After the completion of design, the Office of Design sends the final design plans to the Office of Contracts for letting. The official plans are in PDF format; however, digital files such as MicroStation files and Excel spreadsheets are also sent for reference. The exchanged information may include general design information, typical grading and paving cross-sections, the mainline plan and profile, plans and profiles of affected side roads, plans and profiles of detour roads, construction staging and traffic control, soil information, and other related design works (Iowa DOT 2017b).

- **Office of Contracts to Contractors (ER.P.105):**
  When a contractor is selected, the Office of Contracts then posts all documents to DocExpress and grants access to the contractor. All PDF design plans and digital files that were received from the Office of Design are included.

- **Office of Contracts to Office of Construction and Materials and District Office/RCE (ER.P.105):**
  After the contract is signed, the project information is transferred to the Office of Construction and Materials or the RCE who performs the construction inspection.

- **District Office/RCE to District Office/Maintenance Staff (ER.P.106):**
  After construction is completed, the as-built information, particularly asset locations, should be transferred to the maintenance staff for asset management. However, there is currently no formal information exchange from the construction phase to the maintenance phase.

7.2. Pavement Reconstruction Project (PM.P.2)

7.2.1. Overview

The workflow of a pavement reconstruction project shares common processes with a typical construction project and can be divided into the following phases (see the top row in the process map in Figure 7-2): planning and programming, design, contract development, construction, and operation and maintenance.

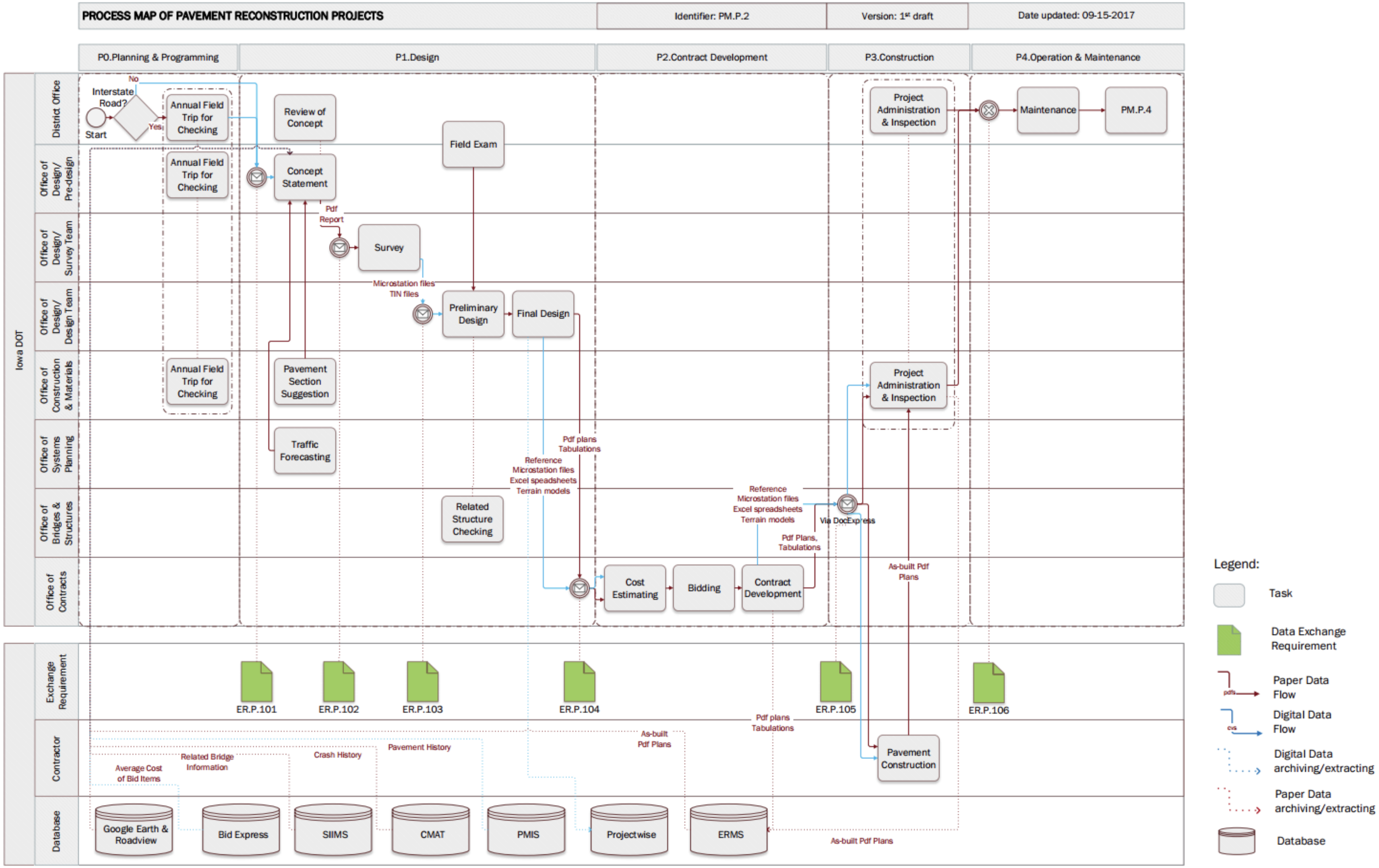

Figure 7-2. Process map of pavement reconstruction projects

Actors involved in the workflow, as presented in the left column of the process map, are the district office, Office of Design, Office of Construction and Materials, Office of Systems Planning, Office of Bridges and Structures, Office of Contracts, and Contractor.

7.2.2. Actors

7.2.2.1. District Office

In the planning phase, the district office is the entity that initiates a new project. For reconstruction of district roads, the district office sends the work order to the Office of Design to develop a design concept. In terms of reconstruction of Interstate roads, an annual field trip to check pavement conditions is organized with participants from the district office, the Office of Design, and the Office of Construction and Materials. Based on the results of the trip, the district office asks the Office of Design to develop the reconstruction concept if needed.

See section 7.1.2 for more information.

7.2.2.2. Office of Design

See section 7.1.2.

7.2.2.3. Office of Systems Planning

See section 7.1.2.

7.2.2.4. Office of Construction and Materials and District Office/RCE

In the planning phase, the Office of Construction and Materials joins the annual field trip with the district office and Office of Design to check the pavement conditions of Interstate roads in order to propose repairs or reconstruction if needed.

See section 7.1.2 for more information.

7.2.2.5. Office of Bridges and Structures

See section 7.1.2.

7.2.2.6. Office of Contracts

See section 7.1.2.

7.2.2.7. Contractor

See section 7.1.2.

7.2.3. Data Exchange

The cases in which data exchange is required are listed below. The details of the data attributes are presented in the ER matrix (see Figures 7-5 through 7-8 at the end of this chapter).

- **District Office to Office of Design/Pre-design Team (ER.P.101):**
  For a pavement reconstruction project, the district office initiates the project and sends relevant information to the pre-design team of the Office of Design to develop a concept design. The exchanged information may include project name, identification, and location; and the expected start and completion dates of the project.

- **Office of Design/Pre-design Team to Office of Design/Survey Team and Design Team:**
  See section 7.1.3.

- **Office of Design/Survey Team to Office of Design/Design Team:**
  See section 7.1.3.

- **Designers to Office of Contracts:**
  See section 7.1.3.

- **Office of Contracts to Contractors:**
  See section 7.1.3.

- **Office of Contracts to Office of Construction and Materials and District Office/RCE:**
  See section 7.1.3.

- **District Office/RCE to District Office/Maintenance Staff:**
  See section 7.1.3.

7.3. Resurfacing, Restoration, or Rehabilitation (3R) Projects (PM.P.3)

7.3.1. Overview

The workflow of a 3R project shares common processes with a typical construction project and can be divided into the following phases (see the top row in the process map in Figure 7-3): planning and programming, design, contract development, construction, and operation and maintenance.

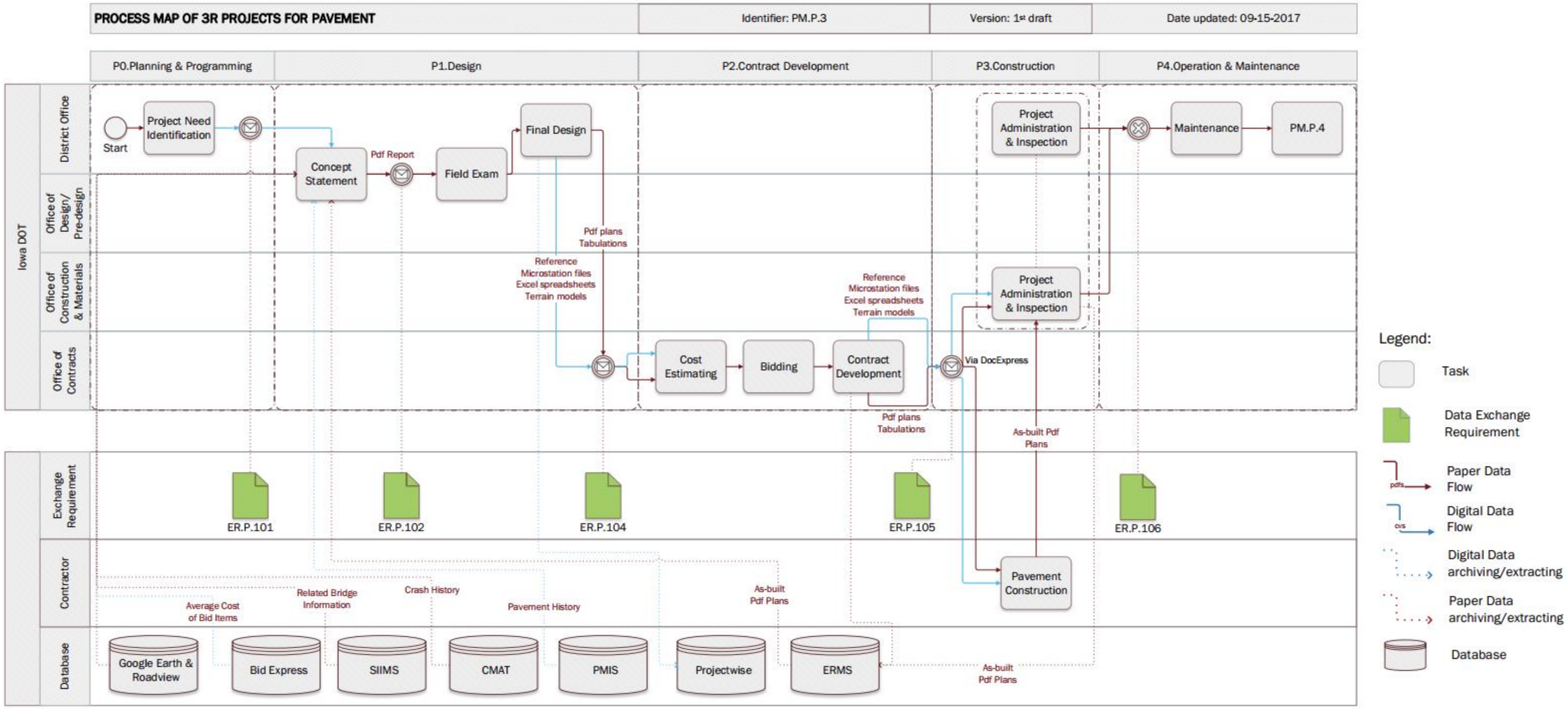

Figure 7-3. Process map of resurfacing, restoration, or rehabilitation (3R) projects

Actors involved in the workflow, as presented in the left column of the process map, are the district office, Office of Design, Office of Construction and Materials, Office of Contracts, and the contractor.

7.3.2. Actors

7.3.2.1. District Office

In the planning phase, the district office initiates a new project. Once the project need is identified, the district office requests that the Office of Design develop a design concept.

The district office also has important roles in other phases, i.e., design (review and approval of design concept, participation in the field examination, and developing a final design by designers in the district office), construction (project administration and inspection by resident construction engineers), and maintenance (operation and maintenance by district maintenance staff).

7.3.2.2. Office of Design

See section 7.1.2.

7.3.2.3. Office of Construction and Materials and District Office/RCE

See section 7.1.2.

7.3.2.4. Office of Contracts

See section 7.1.2.

7.3.2.5. Contractor

See section 7.1.2.

7.3.3. Data Exchange

The cases in which data exchange is required are listed below. The details of the data attributes are presented in the ER matrix (see Figures 7-5 through 7-8 at the end of this chapter).

- **District Office to Office of Design/Pre-design Team (ER.P.101):**
  See section 7.2.3.

- **Office of Design to District Office/Designers (ER.P.102):**
  After the final concept is approved, it is sent to designers of the district office via email as a PDF file. Deliverables for the concept include project data, pavement history, existing conditions and causes of distress, safety considerations, bridge information and updates, crash

history, recommended alternate routes, estimated cost, detour plans, recommendations, special considerations, and funds programmed.

- **Designers to Office of Contracts (ER.P.104):**
  After completion of the design, the designers of the district office send the final design plans to the Office of Contracts for letting. The official plans are in PDF format; however, digital files such as MicroStation files and Excel spreadsheets are also sent for reference. The exchanged information may include general design information, typical grading and paving cross-sections, the mainline plan and profile, plans and profiles of affected side roads, plans and profiles of detour roads, construction staging and traffic control, soil information, and other related design works.

- **Office of Contracts to Contractors (ER.P.105):**
  See section 7.1.3.

- **Office of Contracts to Office of Construction and Materials and District Office/RCE (ER.P.105):**
  See section 7.1.3.

- **District Office/RCE to District Office/maintenance staff (ER.P.106):**
  See section 7.1.3.

7.4. Pavement Maintenance (PM.P.4)

Figure 7-4 presents the process map for pavement maintenance.

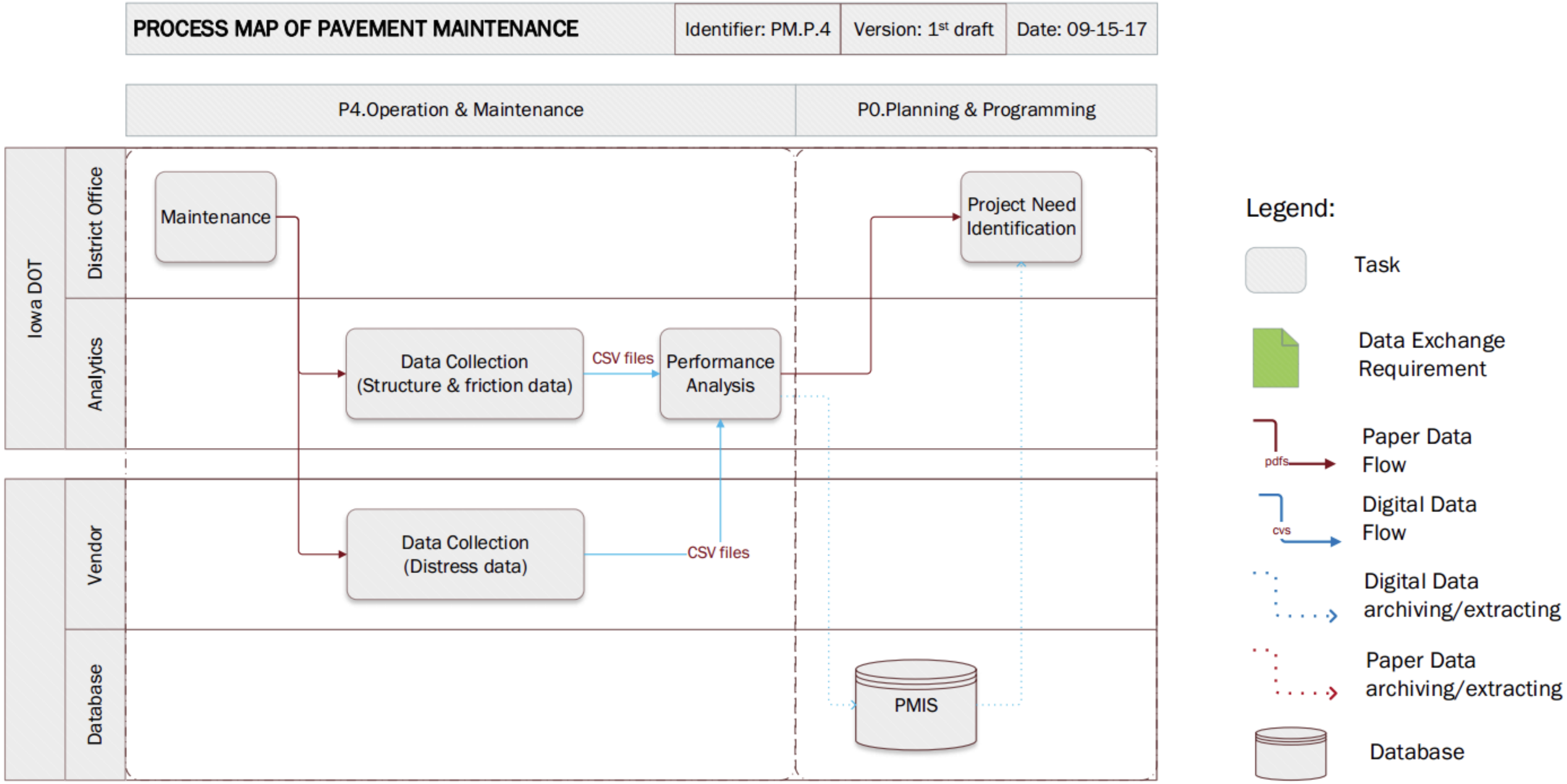

Figure 7-4. Process map of pavement maintenance

While maintenance work is performed by the maintenance team of the district office during the operation and maintenance phase, pavement-related information is also collected to evaluate pavement conditions.

Data are collected by both in-house staff and vendors. Analytics staff from the Iowa DOT collect structure and friction data, and vendors collect distress data. After data collection, the data are used for performance analysis before being stored in PMIS.

The district office then uses the results of the performance analysis and the pavement condition data in PMIS to initiate a new project, if needed.

Exchange Requirement Matrix

Asset type:	**Pavement**	Updated Date:	3/23/2018

Data Exchange Notes

RD	Required, Digital
RP	Required, Paper

Actor Notes

A0. Planner	A1a. Pre-design engineer	A1b. Surveyor	A1.Designer	A2.Office of Contracts	A3. RCE	A3a.Contractor	A4. Maintenance staff

Data attribute group	Data attribute	Description	Comments	Created by	Updated by	Verified by	ER.P.101 to Pre-design Engineer	ER.P.102 to Surveyor & Designer	ER.P.103 to Designer	ER.P.104 to Office of Contracts	ER.P.105 to Contractor	ER.P.106 to Dist. Mnt. Staff
Project	Project name	Name of a project		A0			RD	RD	RD	RD	RD	
	Project ID	Identity of a project		A0			RD	RD	RD	RD	RD	
	Project location	Location of a project		A0			RD	RD	RD	RD	RD	
	Start date	Expected start date of a project		A0	A2						RD	
	End date	Expected completed date of a		A0	A2						RD	
	Proposed duration	The duration of a project		A2								
	Proposed price			A2								
	Bid price			A3a		A3					RD	
	Bid duration			A3a		A3					RD	
	Quantity item			A1a	A1	A3		RP		RD	RD	
General Design Information	Mileage Summary	A table in linear feet and miles of the lengths of project divisions		A1a	A1			RP		RP	RP	
	Design Traffic Data	The Design Traffic Data consists of major controls or services for which a highway is designed.		A1a	A1			RP		RP	RP	
	Type of Work	The statement of the work to be performed		A1a	A1			RP		RP	RP	
	R.O.W. Project Number	This number should match the ROW number in the Project Scheduling System.		A1						RP	RP	
	Design Team	The design contacts		A1						RP	RP	
	Location map			A1a	A1			RP		RP	RP	
Typical grading and paving cross sections	Cross section	A typical cross section include: ditches, shoulders, pavement surfaces, and median width (dimensioned vertically and horizontally); foreslopes and backslopes (labeled with the slope); and subdrains, barriers, and curbs (identified by type)		A1a	A1			RP		RP	RP	
	Cross slope	Be identified by percent with an arrow showing the downward slope direction.		A1a	A1			RP		RP	RP	

Figure 7-5. Pavement data exchange requirement matrix, part 1

Exchange Requirement Matrix

Data Exchange Notes

Asset type:	**Pavement**	Updated Date:	3/23/2018

RD	Required, Digital
RP	Required, Paper

Actor Notes

A0. Planner	A1a. Pre-design engineer	A1b. Surveyor	A1.Designer	A2.Office of Contracts	A3. RCE	A3a.Contractor	A4. Maintenance staff

Data attribute group	Data attribute	Description	Comments	Created by	Updated by	Verified by	ER.P.101 to Pre-design Engineer	ER.P.102 to Surveyor & Designer	ER.P.103 to Designer	ER.P.104 to Office of Contracts	ER.P.105 to Contractor	ER.P.106 to Dist. Mnt. Staff
	The profile grade location	Be shown on the sections.		A1a	A1			RP		RP	RP	
Mainline plan and profile	Alignments and Stationing			A1a	A1			RP		RP	RP	
	Existing features	Existing topographical features		A1b					RD	RP	RP	
	Shading	Shading of the grading surface, the proposed granular surface, the proposed grade/pave surface, the proposed pavement surface, and the temporary pavement surface		A1						RP	RP	
	Lane Lines			A1						RP	RP	
	Pavement Edge Lines			A1						RP	RP	
	Structures	Proposed and existing structures		A1						RP	RP	
	Entrances	Proposed and existing entrances		A1						RP	RP	
	Right-of-Way	Proposed right-of-way lines		A1						RP	RP	
	Utilities			A1						RP	RP	
	Railroad Crossings	Show all railroad crossings within or immediately adjacent to the		A1a	A1			RP		RP	RP	
	Restricted Areas	Environmentally or culturally		A1a	A1			RP		RP	RP	
	Profile and Stationing			A1						RP	RP	
	Ditch Grade Information			A1						RP	RP	
Plan and profile affected side roads	Alignments and Stationing			A1a	A1			RP		RP	RP	
	Existing features	Existing topographical features		A1b					RD	RP	RP	
	Shading	Shading of the grading surface, the proposed granular surface, the		A1						RP	RP	
	Lane Lines			A1						RP	RP	
	Pavement Edge Lines			A1						RP	RP	
	Structures	Proposed and existing structures		A1						RP	RP	
	Entrances	Proposed and existing entrances		A1						RP	RP	
	Right-of-Way	Proposed right-of-way lines		A1						RP	RP	
	Utilities			A1						RP	RP	
	Railroad Crossings	Show all railroad crossings within or immediately adjacent to the		A1a	A1			RP		RP	RP	

Figure 7-6. Pavement data exchange requirement matrix, part 2

Exchange Requirement Matrix

Asset type:	Pavement	Updated Date:	3/23/2018

Actor Notes

A0. Planner	A1a. Pre-design engineer	A1b. Surveyor	A1.Designer	A2.Office of Contracts	A3. RCE	A3a.Contractor	A4. Maintenance staff

Data Exchange Notes

RD	Required, Digital
RP	Required, Paper

Data attribute group	Data attribute	Description	Comments	Created by	Updated by	Verified by	ER.P.101 to Pre-design Engineer	ER.P.102 to Surveyor & Designer	ER.P.103 to Designer	ER.P.104 to Office of Contracts	ER.P.105 to Contractor	ER.P.106 to Dist. Mnt. Staff
	Restricted Areas	Environmentally or culturally sensitive areas		A1a	A1			RP		RP	RP	
	Profile and Stationing			A1						RP	RP	
	Ditch Grade Information			A1						RP	RP	
Plan and profile of detour roads	Alignments and Stationing			A1a	A1			RP		RP	RP	
	Existing features	Existing topographical features		A1b					RD	RP	RP	
	Shading	Shading of the grading surface, the proposed granular surface, the		A1						RP	RP	
	Lane Lines			A1						RP	RP	
	Pavement Edge Lines			A1						RP	RP	
	Structures	Proposed and existing structures		A1						RP	RP	
	Entrances	Proposed and existing entrances		A1						RP	RP	
	Right-of-Way	Proposed right-of-way lines		A1						RP	RP	
	Utilities			A1						RP	RP	
	Railroad Crossings	Show all railroad crossings within or immediately adjacent to the		A1a	A1			RP		RP	RP	
	Restricted Areas	Environmentally or culturally sensitive areas		A1a	A1			RP		RP	RP	
	Profile and Stationing			A1						RP	RP	
	Ditch Grade Information			A1						RP	RP	
Construction staging and traffic control	Traffic locations	Direction of traffic arrows, temporary pavement markings, existing lane lines, critical obstacles.		A1a	A1			RP		RP	RP	
	Structure removal	Proposed construction and pavement removal.		A1a	A1			RP		RP	RP	
	Traffic control devices	Signs, temporary barrier rails, drums, channelizers, and crash cushions.		A1a	A1			RP		RP	RP	
	Temporary structures	Temporary pavement, temporary foreslopes or sheet piling required for staging.		A1a	A1			RP		RP	RP	
Soil information	Soil and soil boring information			A1						RP	RP	
	Borrow soil			A1						RP	RP	

Figure 7-7. Pavement data exchange requirement matrix, part 3

Exchange Requirement Matrix

Asset type:	Pavement	Updated Date:	3/23/2018

Actor Notes

A0. Planner	A1a. Pre-design engineer	A1b. Surveyor	A1.Designer	A2.Office of Contracts	A3. RCE	A3a.Contractor	A4. Maintenance staff

Data Exchange Notes

RD	Required, Digital
RP	Required, Paper

Data attribute group	Data attribute	Description	Comments	Created by	Updated by	Verified by	ER.P.101 to Pre-design Engineer	ER.P.102 to Surveyor & Designer	ER.P.103 to Designer	ER.P.104 to Office of Contracts	ER.P.105 to Contractor	ER.P.106 to Dist. Mnt. Staff
Other design works	Storm sewer			A1						RP	RP	
	Water mains			A1						RP	RP	
	Traffic signal			A1						RP	RP	
	Lighting			A1						RP	RP	
	Bridge and culvert location			A1						RP	RP	
Construction information	Construction milestones	Actual construction schedule		A3a		A3						
Pavement Condition	Pavement Condition Index Version 2.1	PCI is a numerical index developed by the United States Army Corps of Engineers and used to indicate the condition of pavement. The index is based on a field survey of the pavement and is expressed as a value between 0 and 100, with 100 representing excellent condition.		A4								
	Rutting Index			A4								
	International Roughness Index Rating			A4								
	Faulting Index			A4								
	Cracking Index			A4								
	International Roughness Index			A4								
	Friction Value			A4								
	Rut Depth			A4								
	Slabs Cracked			A4								
	Cracking Percent			A4								
	Transverse Cracking Index			A4								
	Longitudinal Cracking Index			A4								
	Longitudinal Wheelpath Cracking Index			A4								
	Alligator Cracking Index			A4								
	Longitudinal Wheelpath Index			A4								
	80% Structural Rating			A4								
	Average Structural Rating			A4								
	Average K Rating			A4								
	Other condition indexes			A4								

Figure 7-8. Pavement data exchange requirement matrix, part 4

8. CURRENT DATA WORKFLOWS OF BRIDGE ASSETS

This chapter captures the current knowledge and practice regarding the workflows and life cycles of bridge asset data, from project initiation to operation and maintenance. Four PMs and one ER matrix for bridge assets are included in this chapter.

8.1. New Bridge Construction Project (PM.B.1)

8.1.1. Overview

The workflow of a new bridge construction project shares common processes with a typical construction project and can be divided into the following phases (see the top row in the process map in Figure 8-1): planning and programming, design, contract development, construction, and operation and maintenance.

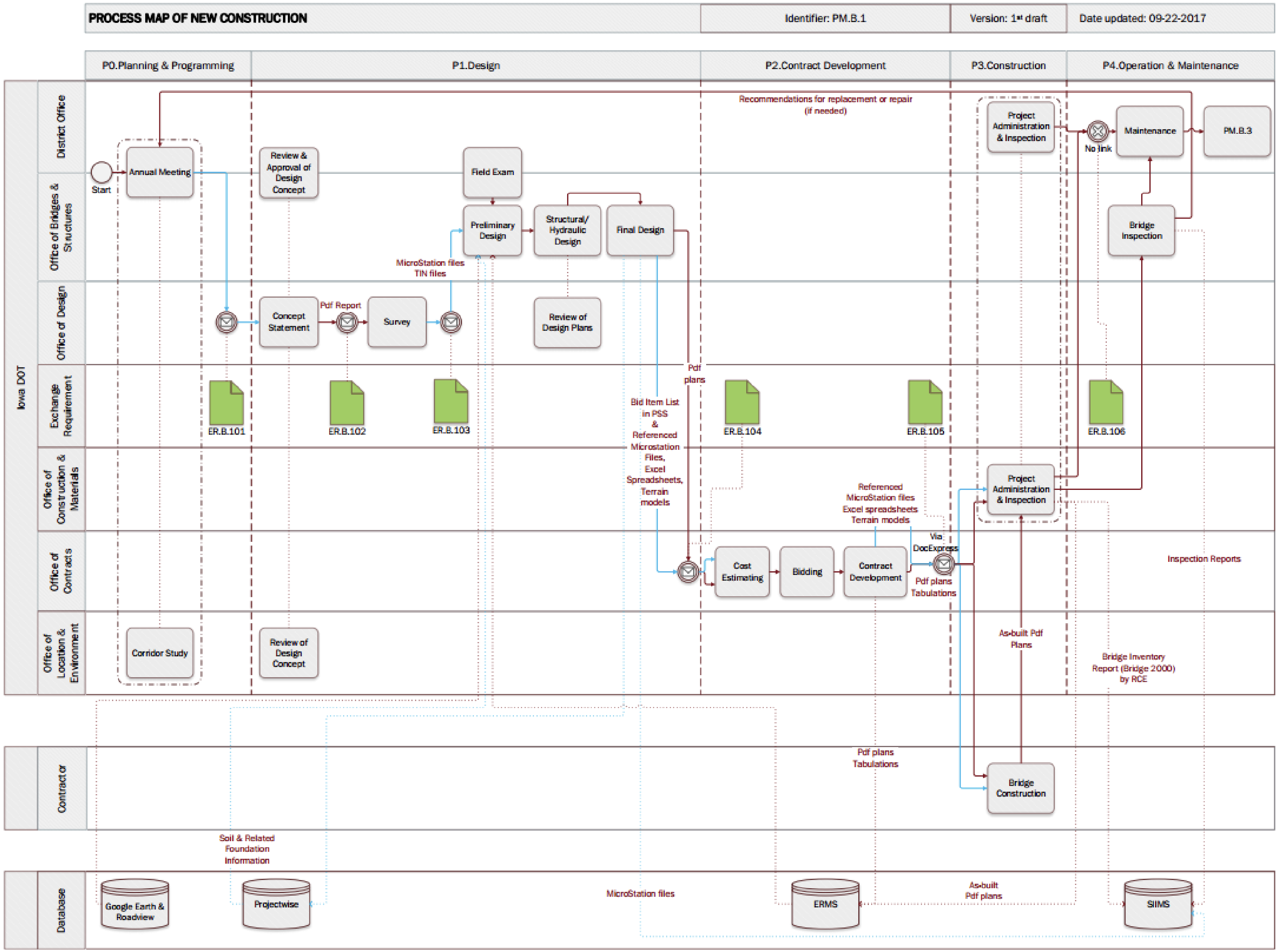

Figure 8-1. Process map of new bridge construction projects[AMK[2]]

Actors involved in the workflow, as presented in the left column of the process map, are the district office, Office of Bridges and Structures, Office of Location and Environment, Office of Design, Office of Construction and Materials, Office of Contracts, and the contractor.

8.1.2. Actors

8.1.2.1. District Office

At the annual district meeting with the Office of Bridges and Structures, new projects that are needed are discussed and identified. The Office of Location and Environment then develops a corridor study before transferring the results to the Office of Design to create a design concept. This is followed by a preliminary design and final design by the Office of Bridges and Structures.

8.1.2.2. Office of Location and Environment

See section 7.1.2.

8.1.2.3. Office of Design

The pre-design/field examination team from the Office of Design takes the corridor study report from the Office of Location and Environment and other input (see PM.P.1) to develop the design concept. Once the draft concept is developed, it is sent to the district office, the Office of Bridges and Structures, and the Office of Location and Environment for review. Based on feedback from those offices, the concept is adjusted to create the final concept. Once the concept is approved, the preliminary survey team of the Office of Design conducts a field survey to obtain information for the development of the design plan.

Although plans for bridges are prepared by the Office of Bridges and Structures, the plans must be coordinated with other related roads and highways. Therefore, the plans should be checked by the Office of Design before the final design is developed.

8.1.2.4. Office of Bridges and Structures

The Office of Bridges and Structures has various roles throughout the project life cycle, from planning to maintenance.

In the planning phase, the Office of Bridges and Structures attends the annual meeting with the district offices to identify new projects that are needed.

After the concept design and field survey are developed and implemented by the Office of Design, the Office of Bridges and Structures is responsible for organizing a field examination with the participation of the district office. All information obtained during the trip is documented to help develop preliminary design plans. With the use of MicroStation, Geopak, and several in-house software programs, designers need to access various resources (e.g., the design concept, the field survey report, the ERMS, and ProjectWise) to develop preliminary design plans or type, size, and location (TS&L) plans. Next, a final design engineer can develop a structural/hydraulic design before creating final design plans with the assistance of various commercial and in-house software applications. Upon the completion of the design, the completed project plan set (in PDF) and referenced digital files are submitted to the Office of Contracts. At this point, all MicroStation files and Excel spreadsheets are saved in the ProjectWise server.

If major changes occur during the construction phase, the district office may request that the Office of Bridges and Structures formulate a plan revision. The revised plans are then also saved in the ProjectWise server.

Finally, bridge maintenance engineers of the Office of Bridges and Structures are responsible for preparing and maintaining an inventory of bridges using SIIMS. The National Bridge Inventory (NBI) data must be collected through various types of inspection processes: initial inspections (the first inspection of a bridge), routine inspections (the inspection interval should not exceed 24 months, or 48 months if approved by the FHWA), and in-depth inspections if needed (Iowa DOT 2015a). Results of the inspections are documented with photographs, sketches, evaluation forms, and notes, which include any recommendations for maintenance, replacement, and repair. Some recommendations are transferred to a district maintenance team. The other suggestions go into the Program Recommendations section in SIIMS and are later evaluated at the annual district meeting with the Office of Bridges and Structures to identify project needs.

8.1.2.5. Office of Construction and Materials and District Office/RCE

See section 7.1.2.

8.1.2.6. Office of Contracts

See section 5.1.2.

8.1.2.7. Contractor

See section 5.1.2.

8.1.3. Data Exchange

The cases in which data exchange is required are listed below. The details of the data attributes are presented in the ER matrix (see Figures 8-5 to 8-8) at the end of this chapter.

- **District Office to Office of Design/Pre-design Team (ER.B.101):**
  At the annual district meeting with the Office of Bridges and Structures, new projects that are needed are discussed and identified. Then, the district office and the Office of Location and Environment determine the most appropriate location for each project. After that, the district office sends relevant information to the pre-design team of the Office of Design to develop a concept design. The exchanged information may include project name, identification, and location; and the expected start and completion dates of the project.

- **Office of Design/Pre-design Team to Office of Design/Survey Team (ER.B.102):**
  After the final concept is approved, it is sent by email in PDF format to the survey team of the Office of Design and other offices. Deliverables for the concept include project description, the need for the project, present facility, traffic estimates, sufficiency ratings, access control, crash history, recommended alternative routes, detour analysis, construction sequence, special considerations, and program status.

- **Office of Design/Survey Team to Office of Bridges and Structures (ER.B.103):**
  For each project, the survey team develops a survey map of all topographic features and goes out to obtain survey information. The team uses global positioning equipment to collect information on the features in real time. After that, the team hand-picks the point clouds to map the features using mapping software to create a 3D model. The output of the survey team is a terrain model in MicroStation and TIN format. When the survey is completed, the survey team places the survey data in ProjectWise and informs the other teams and offices. Designers use TIN files to load topographic features for developing the design plans.

- **Office of Bridges and Structures to Office of Contracts (ER.B.104):**
  After the completion of design work, the Office of Bridges and Structures sends the final design plans to the Office of Contracts for letting. The official plans are in PDF format; however, digital files such as MicroStation files and Excel spreadsheets are also sent for reference. The exchanged information may include general design information, situation plans, staking diagrams, foundation and substructure details, superstructure details, and other related design works (Iowa DOT 2018).

- **Office of Contracts to Contractors (ER.B.105):**
  When a contractor is selected, the Office of Contracts then posts all documents to DocExpress and grants access to the contractor. The packages available for the contractor to download include all PDF design plans created by the designer as well as those developed by the Office of Contracts.

- **Office of Contracts to Office of Construction and Materials and District Office/RCE (ER.B.105):**
  After the contract is signed, the project information is transferred to the Office of Construction and Materials or the RCE who performs the construction inspection.

- **District Office/RCE to District Office/Maintenance Staff (ER.B.106):**
  After construction is completed, the as-built information, particularly asset locations, should be transferred to maintenance staff for asset management. However, there is currently no formal information exchange from the construction phase to the maintenance phase.

8.2. Bridge Reconstruction Project (PM.B.2)

8.2.1. Overview

The workflow of a bridge reconstruction project shares common processes with a typical construction project and can be divided into the following phases (see the top row in the process map in Figure 8-2): planning and programming, design, contract development, construction, and operation and maintenance.

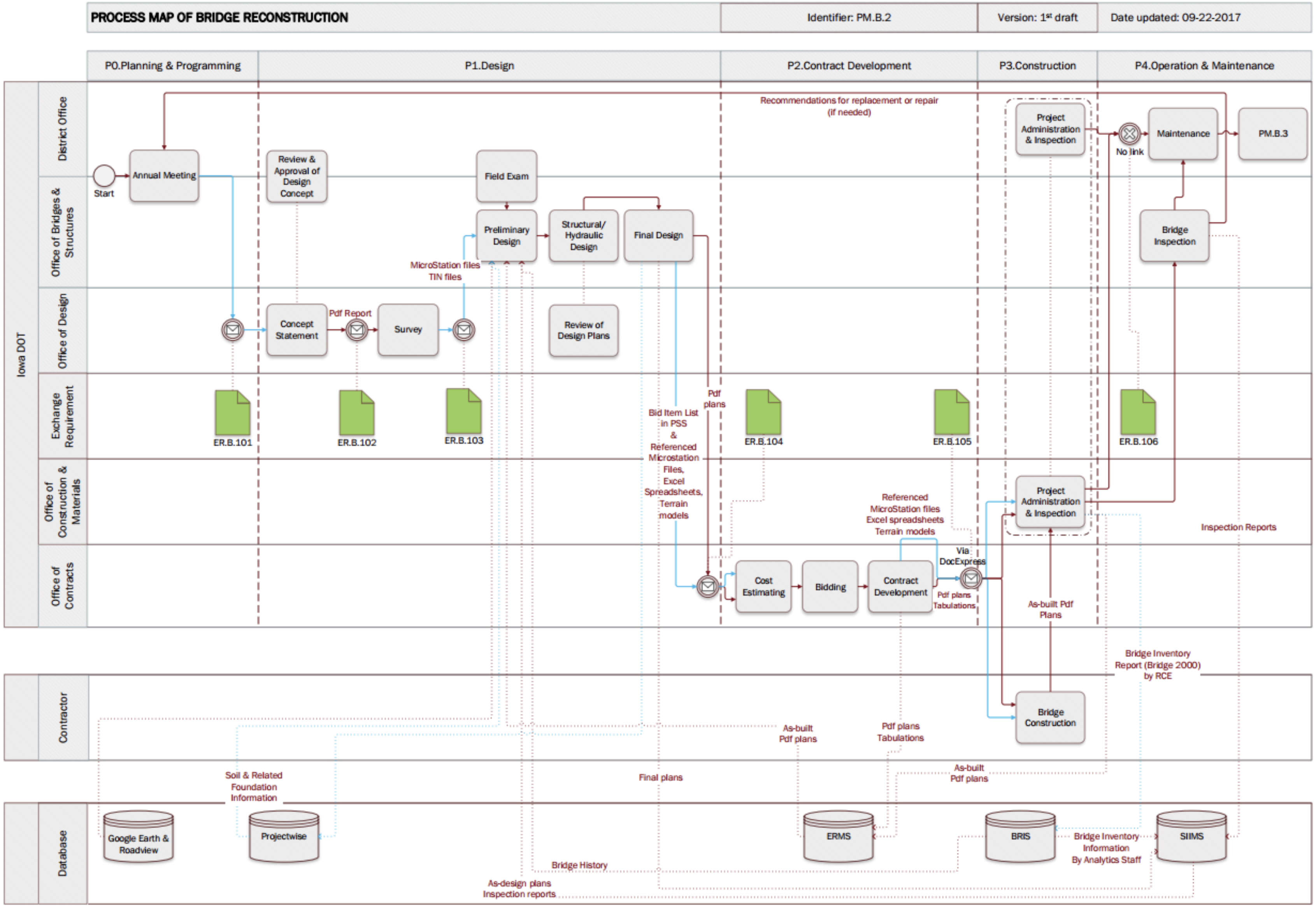

Figure 8-2. Process map of bridge reconstruction projects

Actors involved in the workflow, as presented in the left column of the process map, are the district office, Office of Bridges and Structures, Office of Design, Office of Construction and Materials, Office of Contracts, and the contractor.

8.2.2. Actors

8.2.2.1. District Office

At the annual district meeting with the Office of Bridges and Structures, new projects that are needed are discussed and identified. After that, the district office requests that the Office of Design develop a design concept before transferring the results to the Office of Bridge and Structures to create a preliminary design and final design.

8.2.2.2. Office of Design

See section 8.1.2.

8.2.2.3. Office of Bridges and Structures

See section 8.1.2.

8.2.2.4. Office of Construction and Materials and District Office/RCE

See section 7.1.2.

8.2.2.5. Office of Contracts

See section 5.1.2.

8.2.2.6. Contractor

See section 5.1.2.

8.2.3. Data Exchange

The cases in which data exchange is required are listed below. The details of the data attributes are presented in the ER matrix (see Figures 8-5 through 8-8) at the end of this chapter.

- **District Office to Office of Design/Pre-design Team (ER.B.101):**
  At the annual district meeting with the Office of Bridges and Structures, new projects that are needed are discussed and identified. Then, the district office sends relevant information to the pre-design team of the Office of Design to develop a concept design. The exchanged information may include project name, identification, and location; and the expected start and completion dates of the project.

- **Office of Design/Pre-design Team to Office of Design/Survey Team (ER.B.102):**
  See section 8.1.3.

- **Office of Design/Survey Team to Office of Bridges and Structures (ER.B.103):**
  See section 8.1.3.

- **Office of Bridges and Structures to Office of Contracts (ER.B.104):**
  See section 8.1.3.

- **Office of Contracts to Contractors (ER.B.105):**
  See section 8.1.3.

- **Office of Contracts to Office of Construction and Materials and District Office/RCE (ER.B.105):**
  See section 8.1.3.

- **District Office/RCE to District Office/Maintenance Staff (ER.B.106):**
  See section 8.1.3.

8.3. Programmed Repair Project for Letting (PM.B.3)

8.3.1. Overview

The workflow of a programmed repair project shares common processes with a typical construction project and can be divided into the following phases (see the top row in the process map in Figure 8-3): planning and programming, design, contract development, construction, and operation and maintenance.

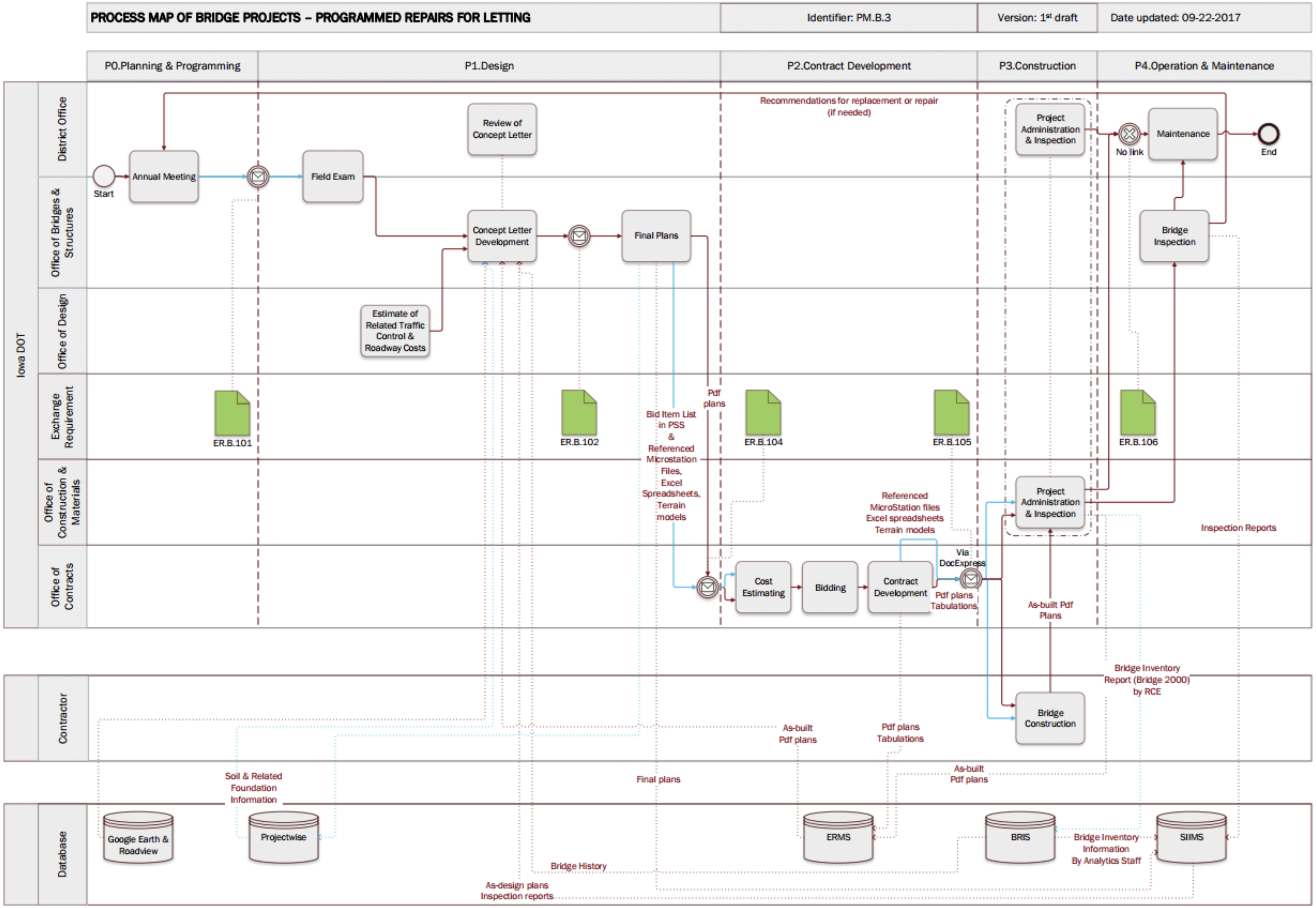

Figure 8-3. Process map of programmed bridge repair projects for letting

Actors involved in the workflow, as presented in the left column of the process map, are the district office, Office of Bridges and Structures, Office of Design, Office of Construction and Materials, Office of Contracts, and the contractor.

8.3.2. Actors

8.3.2.1. District Office

At the annual district meeting with the Office of Bridges and Structures, the offices initiate programmed repair projects. After that, a field examination is conducted to verify the needs for repairs and determine the details of those repairs. The results are then transferred to the Office of Bridges and Structures to develop a concept letter with the district's approval.

8.3.2.2. Office of Bridges and Structures

The Office of Bridges and Structures cooperates with the district office in the initiation of a new programmed repair project. Designers from the Office of Bridges and Structures, along with representatives of the district, conduct a field trip to review the scope of repairs needed. After that, the designer writes a concept letter with a detailed description of the work that needs to be done and an estimated cost to the district maintenance manager for review and approval. To develop the concept letter, the designer mainly leverages the results of the field trip, the bridge information in the ERMS and SIIMS, and an estimate of related traffic control and roadway costs from the Office of Design. Once the concept is approved, it is used to develop final plans.

See section 8.1.2 for more information.

8.3.2.3. Office of Design

Because a repair project may involve pavement on adjacent roads and highways, the Office of Design provides information on related roads and highways to the Office of Bridges and Structures if requested.

8.3.2.4. Office of Construction and Materials and District Office/RCE

See section 7.1.2.

8.3.2.5. Office of Contracts

See section 5.1.2.

8.3.2.6. Contractor

See section 5.1.2.

8.3.3. Data Exchange

The cases in which data exchange is required are listed below. The details of the data attributes are presented in the ER matrix (see Figures 8-5 through 8-8 at the end of this chapter).

- **District Office to Office of Bridges and Structures (ER.B.101):**
  The district office is the entity that initiates repair projects in cooperation with the Office of Bridges and Structures. The exchanged information may include project name, identification, and location; and the expected start and completion dates of the project.

- **Office of Bridges and Structures: from Concept Statement to Final design (ER.B.102):**
  Unlike for new and replacement projects, the Office of Bridges and Structures is in charge of developing the concept to determine the repairs in detail, including the work that needs to be done and the estimated cost. The final concept is then used to develop the final plans.

- **Office of Bridges and Structures to Office of Contracts (ER.B.104):**
  See section 8.1.3.

- **Office of Contracts to Contractors (ER.B.105):**
  See section 8.1.3.

- **Office of Contracts to Office of Construction and Materials and District Office/RCE (ER.B.105):**
  See section 8.1.3.

- **District Office/RCE to District Office/Maintenance Staff (ER.B.106):**
  See section 8.1.3.

8.4. Emergency Repair Project for Letting (PM.B.4)

No funds are programmed for emergency repairs that are mainly necessitated by collisions between vehicles and bridges. The Office of Bridges and Structures is responsible for obtaining contingency funds to start such projects. Otherwise, the procedure is similar to the procedure for programmed repair projects (see Figure 8-4).

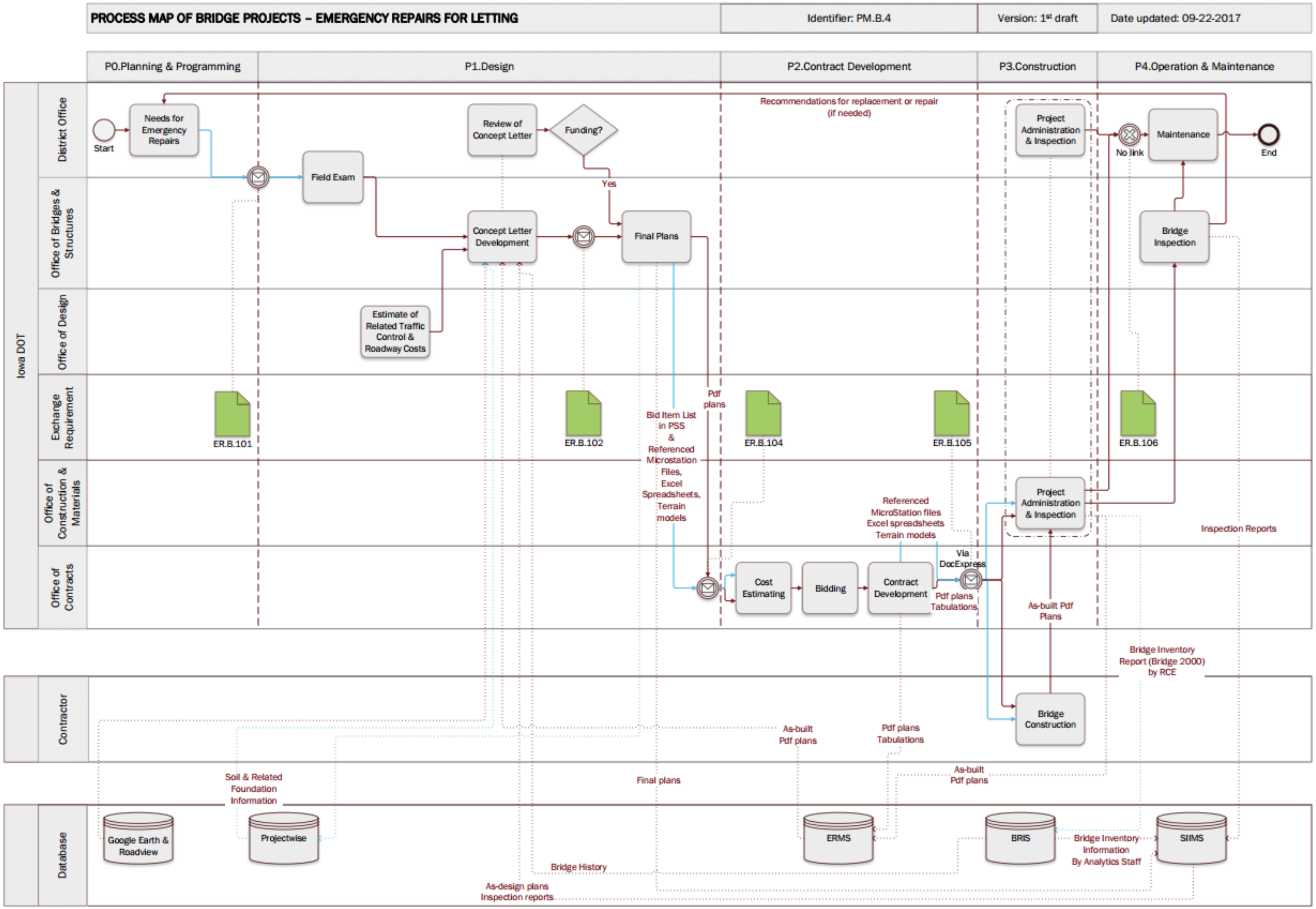

Figure 8-4. Process map of emergency bridge repair project for letting

Exchange Requirement Matrix

Asset type:	Bridges	Updated Date:	3/23/2018					
Actor Notes								
A0. Planner	A1a. Pre-design engineer	A1b. Surveyor	A1.Designer	A2. Office of Conntracts	A3. RCE	A3a.Contractor	A4. Maintenance staff	

Data Exchange Notes

RD	Required, Digital
RP	Required, Paper

Data attribute group	Data attribute	Description	Comments	Created by	Updated by	Verified by	ER.B.101 to Pre-design Engineer	ER.B.102 to Surveyor & Designer	ER.B.103 to Desinger	ER.B.104 to Office of Contracts	ER.B.105 to Contractor	ER.B.106 to Dist. Mnt. Office
Project	Project name	Name of a project		A0			RD	RD	RD	RD	RD	
	Project ID	Identity of a project		A0			RD	RD	RD	RD	RD	
	Project location	Location of a project		A0			RD	RD	RD	RD	RD	
	Start date	Expected start date of a project		A0	A2						RD	
	End date	Expected completed date of a		A0	A2						RD	
	Proposed duration	The duration of a project		A2								
	Proposed price			A2								
	Bid price			A3a		A3					RD	
	Bid duration			A3a		A3					RD	
	Quantity item			A1a		A3		RP		RD	RD	
General Design Information	Design purpose	Ex.: Design for replacement of the existing bridge.		A1a	A1			RP		RP	RP	
	Structure type and size	Ex.: A new 150'-0 x 40'-0 continuous concrete slab bridge.		A1a	A1			RP		RP	RP	
	Staging sequence	Staged construction to maintain traffic.		A1a	A1			RP		RP	RP	
	Span Description	The lengh of each span.		A1a	A1			RP		RP	RP	
	Station of bridge	Mainline bridge station.		A1a	A1			RP		RP	RP	
	Turn in date	The date that designers issue the final plans.		A1						RP	RP	
	Soil sheets	Boring hole location, date drilled, groundwater level, soil layer thickness, core data, etc.		A1						RP	RP	
	Paint color	Paint color specified by Federal Standard Color Number.		A1						RP	RP	
	Bridge standard			A1						RP	RP	
	Work type	The work type which represents the majority of the work in the project. Ex.: Bridge New-Steel Girder.		A1a	A1			RP		RP	RP	
	FRA crossing number	FRA stands for Federal Railroad Administration.		A1						RP	RP	
	Traffic data	Traffic estimate including % trucks.		A1a				RP		RP	RP	
	Location map			A1a	A1			RP		RP	RP	
	Traffic control plan			A1a	A1			RP		RP	RP	
	Pollution prevention plan			A1						RP	RP	
	Design history			A1a	A1			RP		RP	RP	
	Specification note	Design specifications and construction specifications.		A1						RP	RP	
	Design Stresses	Design stresses for materials (reinforcing steel, concrete, structural steel).		A1						RP	RP	

Figure 8-5. Bridge data exchange requirement matrix, part 1

Exchange Requirement Matrix

Data Exchange Notes

RD	Required, Digital
RP	Required, Paper

Asset type:	Bridges	Updated Date:	3/23/2018

Actor Notes

A0. Planner	A1a. Pre-design engineer	A1b. Surveyor	A1.Designer	A2. Office of Conntracts	A3. RCE	A3a.Contractor	A4. Maintenance staff

Data attribute group	Data attribute	Description	Comments	Created by	Updated by	Verified by	ER.B.101 to Pre-design Engineer	ER.B.102 to Surveyor & Designer	ER.B.103 to Desinger	ER.B.104 to Office of Contracts	ER.B.105 to Contractor	ER.B.106 to Dist. Mnt. Office
Situation plan	Location information	Road, river, township, county, latitude, longitude.		A1a	A1			RP		RP	RP	
	Hydraulic data	Drainage area, stream slope, backwater, etc.		A1						RP	RP	
	Profile data	Check for coordination with roadway design.		A1b	A1				RD	RP	RP	
	Shoulder and approach pavement widths and slopes	Widths and slopes of shoulder and approach pavement of a main crossing roadway.		A1b	A1				RD	RP	RP	
	Horizontal curve data	To check for coordination with roadway.		A1b	A1				RD	RP	RP	
	Alignments of approach roadway	Alignments and stationing along center line of approach roadway.		A1b	A1				RD	RP	RP	
	Ditches and pipes	To check for coordination with roadway.		A1b	A1				RD	RP	RP	
	Removal information	Any removals need performing.		A1b	A1			RP		RP	RP	
	Slope protection	Method of protecting the slope is shown.		A1						RP	RP	
	Overhead clearance	Overhead clearance points are		A1						RP	RP	
	Guardrail	Related guardrails are shown.		A1a	A1			RP		RP	RP	
	Horizontal clearance	Horizontal clearance with other structures, especially railroads.		A1a	A1			RP		RP	RP	
	Existing structures	Existing structures are shown.		A1a	A1			RP		RP	RP	
	Future structures	Future structures are shown.		A1a	A1			RP		RP	RP	
	Stream or crossing highway	Name of stream or crossing		A1a	A1			RP		RP	RP	
	Pertinent structures and features	Structures and features are close enough to influence construction.		A1a	A1			RP		RP	RP	
	Utility information	Utility information is shown on situation plan.		A1						RP	RP	
	Excavation	Types and channel excavation limits with slopes, dimensions, and elevations.		A1						RP	RP	
	Elevations	Elevations of abutments, piers, footing, etc.		A1						RP	RP	
	Minimum clearance	Location and dimension of minimum clearance under		A1						RP	RP	
	Piling description	Length and type of piles		A1						RP	RP	
	Pier type	Pier type is labeled.		A1						RP	RP	

Figure 8-6. Bridge data exchange requirement matrix, part 2

Exchange Requirement Matrix

Data Exchange Notes

RD	Required, Digital
RP	Required, Paper

Asset type:	Bridges	Updated Date:	3/23/2018

Actor Notes

A0. Planner	A1a. Pre-design engineer	A1b. Surveyor	A1.Designer	A2. Office of Conntracts	A3. RCE	A3a.Contractor	A4. Maintenance staff

Data attribute group	Data attribute	Description	Comments	Created by	Updated by	Verified by	ER.B.101 to Pre-design Engineer	ER.B.102 to Surveyor & Designer	ER.B.103 to Desinger	ER.B.104 to Office of Contracts	ER.B.105 to Contractor	ER.B.106 to Dist. Mnt. Office
Staking diagram	Gutterline dimension	Gutterline dimension at abutment.		A1						RP	RP	
	Center line of approach roadway.	Center line of approach roadway is shown as the primary staking control line.		A1						RP	RP	
	Substructure dimension	Provide dimension of substructure units but do not shown pile		A1						RP	RP	
Foundation & Substructure details	Pier cap information	Details of dimension, location, concrete, steel structure, anchor bolts, reinforcement, painting, etc.		A1						RP	RP	
	Column information	Details of dimension, location, concrete, steel structure, anchor bolts, reinforcement, painting, etc.		A1						RP	RP	
	Footing	Details of dimension, location, concrete, steel structure, anchor bolts, reinforcement, painting, etc.		A1						RP	RP	
	Pile Bent	Pile type and size.		A1						RP	RP	
	Abutement	Pile arrangement, pile batter, pre-bore requirement, reinforcing details, concrete, concrete sealer, steel structures, etc.		A1						RP	RP	
Superstructure details	Deck layout	Deck placement sequence, transverse joint type, longitudinal and transverse construction joint details, dimensions, reinforcing		A1						RP	RP	
	Slab elevation layout	Deck elevations provided along the centerline of approach roadway, all beam lines, each gutter line and longitudinal construction joint if required.		A1						RP	RP	
	Girder Details (Continuous welded plate girder)	Shear stud, stiffener details, weathering steel, painting, welding, flange dimension, tension and compression zones, anchor		A1						RP	RP	
	Beam Details (Pretensioned prestressed concrete beam)	Strand projection detail, shear reinforcement, vent holes, concrete dimension, concrete sealer detail,		A1						RP	RP	

Figure 8-7. Bridge data exchange requirement matrix, part 3

Exchange Requirement Matrix

Data Exchange Notes

Asset type:	Bridges	Updated Date:	3/23/2018

RD	Required, Digital
RP	Required, Paper

Actor Notes

A0. Planner	A1a. Pre-design engineer	A1b. Surveyor	A1.Designer	A2. Office of Conntracts	A3. RCE	A3a.Contractor	A4. Maintenance staff

Data attribute group	Data attribute	Description	Comments	Created by	Updated by	Verified by	ER.B.101 to Pre-design Engineer	ER.B.102 to Surveyor & Designer	ER.B.103 to Desinger	ER.B.104 to Office of Contracts	ER.B.105 to Contractor	ER.B.106 to Dist. Mnt. Office
Other design works	Barrier rail	Electric conduit, junction boxes, special rail requirement, rail elevation, concrete type, stainless steel, etc.		A1						RP	RP	
	Subdrain/Slope protection details	Subdrain outlet elevations, revetment stone outlet details, etc.		A1						RP	RP	
	Lighting details	Conduit details, elevation view of conduit along bridge, light pole conduit, etc.		A1						RP	RP	
	Approach sidewalk	For bridges with sidewalks the sidewalk approach slab detail sheet is included.		A1						RP	RP	
	Abutment backfill details	Geotextile fabric, porous backfill, soil backfill, subbase, etc.		A1						RP	RP	
Construction information	Construction milestones	Actual bridge construction schedule		A3a		A3						
Bridge Condition	Deck Rating			A4								
	Superstructure Rating			A4								
	Substructure Rating			A4								
	Channel Protection Rating			A4								
	Culverts Rating			A4								
	Operating Rating Method			A4								
	Operating Method			A4								
	Inventory Rating Method			A4								
	Inventory Rating			A4								
	Structural Evaluation			A4								
	Deck Geometry			A4								
	Sufficiency Rating			A4								
	Sufficiency Rating Date			A4								
	FHWA Sufficiency			A4								
	Other condition indexes			A4								

Figure 8-8. Bridge data exchange requirement matrix, part 4

9. LIMITATIONS AND SUGGESTIONS

9.1. Limitations

Figure 9-1 shows the current data flow throughout a project's life cycle at the Iowa DOT.

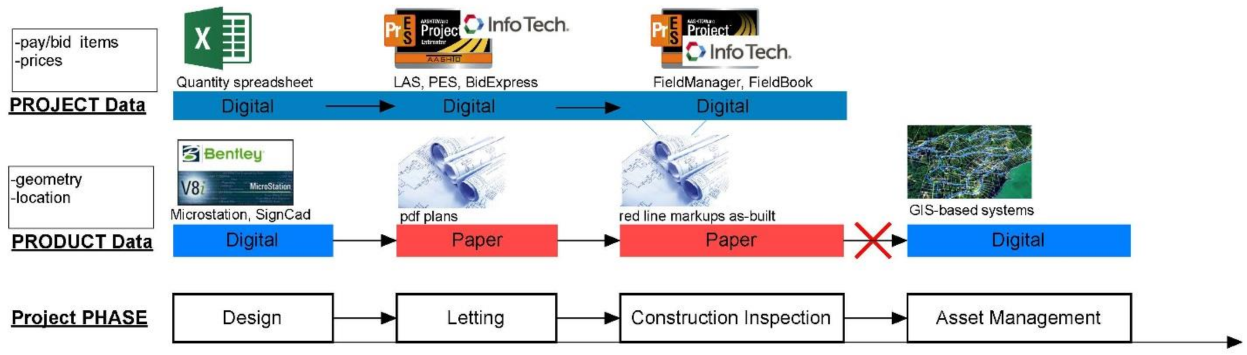

Figure 9-1. Current data flow within the Iowa DOT

Data related to a transportation project can be classified as contract data or asset data. Contract data are the items associated with pay items, bid prices, schedule, etc., which are mainly used for project administration purposes. Asset data are related to geometric dimensions and the geographic locations of physical objects. As shown in Figure 9-1, while contract data are smoothly transferred between divisions, the flow of asset data is apparently disconnected, especially as shown by a complete blockage between construction and asset management. The difference in the data desired is a major contribution to this lack of a seamless digital data transfer through an asset's life cycle.

Below are several specific limitations of the current workflow:

- The digital life of asset data officially ends immediately after the design phase. Although designers send both digital files and PDF plans to the Office of Contracts for letting, the digital files (MicroStation files, Excel spreadsheets, and terrain models) are only used for reference. In many cases, the information from the digital files and the PDF plans is contradictory, and the PDF plans are considered to be the official contract documents.

- Cost estimation is primarily made manually. Most quantities are manually calculated. Unit prices of bid items are estimated based on historical data from the last 12 months, and checked manually to ensure their similarity with historical data.

- Mobile LiDAR is used only on a limited basis in survey work and is mostly used for Interstate projects.

- After collecting survey data in the field, surveyors have to hand-pick point clouds to map features using mapping software to create terrain models.

- When receiving terrain models and MicroStation files from the survey team, designers do not use the received files to continue their design work. They just take the input data and start their work in a blank file.

- Because the digital files that contractors receive from the Office of Contracts are just for reference, in many cases those files may be incorrect. Contractors have to spend time and money to correct the files for use in automated machine guidance. Moreover, in the end, those corrected files are not stored for further use.

- As-built data are created by adding red-line markups to the design PDF plans. This format is ultimately not machine-readable and is thus challenging for asset managers to translate into a useful format.

- In addition to as-built documents, IDRs are a great potential source to extract as-built data for an asset. IDRs are supposed to provide information that can verify whether features are constructed in accordance with the design. However, under the current practice, IDRs capture very limited geometric or geolocation-related data. In addition, locations in IDRs are captured using a linear reference system (mileposts, stations) that is not compatible with latitude/longitude data in an asset management system.

- Data transfer from the construction phase to the asset management phase is lacking.

9.2. Suggestions for Improvement

9.2.1. Ideal Process Map

Figure 9-2 illustrates an ideal workflow, where digital data generated from the design phase is transferred through the letting phase to the construction phase.

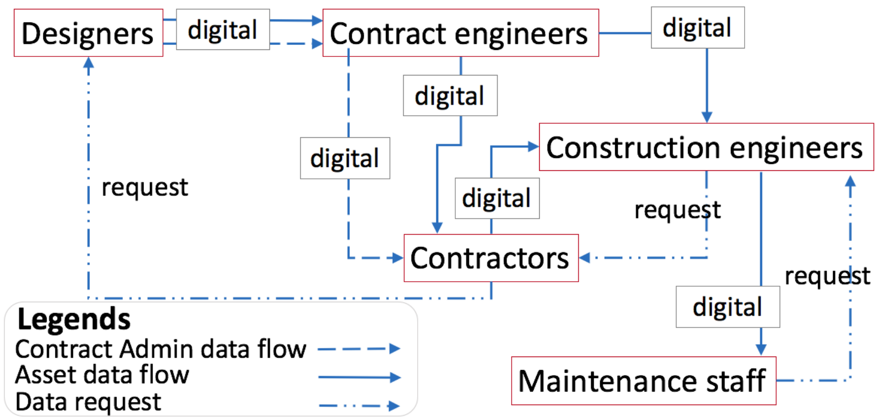

Figure 9-2. Ideal digital data workflow

Once verified, as-built data are presented in a digital format, so it is possible for the asset manager to reuse data created upstream.

9.2.2. Specific Suggestions for Improvement

- **Design MicroStation files and database tables**. Designers should add geocoded location attributes to design elements in their MicroStation files. Although Iowa DOT is now using Low Distortion Projections (LDP) for all new projects, extra efforts are needed to standardize and then integrate LDP into the design files. These documents should be passed on to project inspectors for verification purposes. Designers could also create database tables summarizing designed attribute details, including asset location. In the construction phase, contractors should ensure that they follow the design drawings. In order to check the permitted construction tolerance, they need to determine the exact location of the asset to compare with the designed location. After the as-built location is checked and approved by the construction engineers, it could be transferred to maintenance staff for further use.

- **Official digital files for letting**. Both digital files and PDF plans that the Office of Contracts receives from designers should include the same information. No contradiction between digital files and PDF plans should be allowed. Then, the Office of Contracts can use both types of documents for letting. Design plans available in digital format would help the contractor significantly reduce the efforts needed to create digital as-built documents.

- **Survey work.** Mobile LiDAR use should be expanded. Data processing of survey data, such as feature extraction, should be automated.

- **Cost estimation**. Manual estimations of quantities should be reduced. Each item of historical bid data should have several attributes that can be used to filter out inappropriate bid items for unit price estimates.

- **Digital terrain models.** Digital terrain models created by the survey team should be directly leveraged by designers when developing design plans. The models could be updated by the contractor and further verified by project inspectors during the construction phase. Then, the models should be stored in the system for further use.

- **As-built plans in MicroStation files**. Construction contracts should include a provision asking contractors to submit as-built plans as MicroStation files. This digital format would enable asset managers to efficiently reuse inventory data generated in upstream phases.

- **Construction inspection.** IDRs should capture the locations of construction activities using global positioning system (GPS) devices rather than the linear referencing system. Project inspectors can use a particular collector app to efficiently collect geocoded data. Construction inspectors are to be trained in using the app Collector for ArcGIS in 2018. They will be responsible for updating the inventory of new features including signs, culverts, traffic barriers, lighting, and walls. They will also be responsible for retiring features as these are replaced in the system, and updating information for features that are altered in some way by construction. This focus is mainly on the inventory side of the data collection system.

- **Connecting construction and asset management.** Formal communication channels between the asset management and construction phases should be established. At the end of the construction phase, geocoded verified product data need to be transferred to the asset management phase.

10. CONCLUSIONS

The aim of this research was to help professionals working in the Iowa DOT better understand the flow of digital data and information during the project life cycle for various types of transportation assets, including pavements, bridges, culverts, signs, and guardrails. Despite the increasing availability of project data in digital format due to the use of such advanced computerized technologies as 3D modeling and project administration systems, data handover still relies heavily on paper or electronic paper-based documents. The research team's interviews with highway professionals revealed that asset maintenance personnel are required to manually locate data in project documents and merge the data into asset management systems. In many cases, asset inventory data must be collected a second time from the field using mobile devices. Properly transferring the appropriate asset data in the right format to the operation and maintenance phases will reduce the costs of duplicating data collection efforts, which will, in turn, enhance productivity and reduce operation costs.

Focus group discussions and interviews with highway professionals were conducted to capture their knowledge about the data workflows. For each type of asset, a series of meetings with participants was conducted. In addition, an extensive review of the literature, manuals, project documents, and software applications centering on data attributes was also conducted. These data were refined and organized in IDM documents in which the processes and data exchange relationships among the project players were visually represented. The study developed five separate IDMs for five different types of assets. Each IDM is composed of several PMs and one ER matrix. In total, 15 PMs and 5 ER matrices were developed.

The PMs offer a better understanding of the overall workflow, particularly regarding the activities and data sharing flow throughout a construction project. These PMs can help practitioners better understand the work process and interactions between involved parties for different types of projects (i.e., new construction, reconstruction, repair, and maintenance) and different kinds of assets (signs, guardrails, culverts, pavements, and bridges).

The ER matrices show who needs what data and who can provide the data. Digital data could be categorized into contract data and asset data. Some examples of the former include the unit price and quantity of bid items and the project schedule, and the latter may include geometry and material, location, identification, and condition. While contract data are smoothly transferred between divisions, the flow of asset data is apparently disconnected, especially between the construction and asset management phases. Actors contributing to the life of a piece of data are classified as the creator, updater, verifier, and consumer. Of these participants, the designer generates most of the asset information, while the contractor and asset manager are the most important data consumers. From the maintenance point of view, asset location, geometry, material, and construction date are the data of greatest interest. These types of data are originally created by different actors, including designers and contractors.

In addition, some limitations within the current workflow were identified. For example, as-built data are created by adding red-line markups to the design PDF plans (i.e., not in machine-readable format). This makes it difficult for the asset manager to translate the information into a useful format. Also, an ideal process map and suggestions for improvement were proposed to further streamline the workflow throughout the project life cycle and reduce duplicate data collection efforts during the operation and maintenance phases.

REFERENCES

BuildingSMART. 2016. *Information Delivery Manuals*. http://iug.buildingsmart.org/idms/information-delivery-manuals.

Berard, O. and J. Karlshoej. 2012. Information delivery manuals to integrate building product information into design. *Journal of Information Technology in Construction,* Vol.17**,** pp. 64–74.

Eastman, C., Y.-S. Jeong, R. Sacks, and I. Kaner. 2009. Exchange Model and Exchange Object Concepts for Implementation of National BIM Standards. *Journal of Computing in Civil Engineering*, Vol. 24**,** No. 1, pp. 25–34.

Hoeber, H. and D. Alsem. 2016. Life-cycle information management using open-standard BIM. *Engineering, Construction, and Architectural Management,* Vol. 23**,** No. 6, pp. 696–708.

Iowa DOT. 2015a. *Bridge Inspection Manual.* Office of Bridges and Structures, Iowa Department of Transportation, Ames, IA. https://siims.iowadot.gov/IowaDOT_BridgeInspectionManual.pdf.

Iowa DOT. 2015b. *Construction Manual.* Electronic Reference Library, Iowa Department of Transportation, Ames, IA. https://iowadot.gov/erl/current/CM/Navigation/nav.htm.

Iowa DOT. 2017a. *Final Bridge Design Software.* Office of Bridges and Structures, Iowa Department of Transportation, Ames, IA. https://iowadot.gov/bridge/automation-tools/final-design-software.

Iowa DOT. 2017b. *Design Manual.* Office of Design, Iowa Department of Transportation, Ames, IA. https://iowadot.gov/design/design-manual.

Iowa DOT. 2018. *Bridge and Culvert Plan Checklist.* Office of Bridges and Structures, Iowa Department of Transportation, Ames, IA. https://iowadot.gov/bridge/design-policies/bridge-and-culvert-plan-checklist.

Jallow, A. K., S. Lee, F. Castronovo, Y. Zhang, S. Chunduri, and J. I. Messner. 2013. Process-based information exchanges mapping for energy-efficient retrofit projects. Paper presented at the 2013 ASCE International Workshop on Computing in Civil Engineering, June 23–25, Los Angeles, CA. pp. 234–241.

Karlshøj, J., P. Borin, M. Carradori, M. Scotton, and C. Zanchetta. 2016. Delivering of COBie data—focus on curtain walls and building envelopes. Proceedings of the 11th European Conference on Product and Process Modelling: eWork and eBusiness in Architecture, Engineering, and Construction, September 7–9, Limassol, Cyprus. pp. 183–190.

Klobut, K., T. Mäkeläinen, A. Huovila, J. Hyvärinen, and J. Shemeikka. 2016. KPI framework for energy-efficient buildings and neighbourhoods. Proceedings of the 11th European Conference on Product and Process Modelling: eWork and eBusiness in Architecture, Engineering, and Construction. September 7–9, Limassol, Cyprus. pp. 309–314.

National Institute of Building Sciences. 2007. *United States National Building Information Modeling Standard,Version 1.0, Part 1: Overview, Principles, and Methodologies.* Facilities Information Council, National BIM Standard. Washington, DC. http://www.1stpricing.com/pdf/NBIMSv1_ConsolidatedBody_Mar07.pdf.

Nawari, N. 2011. Standardization of structural BIM. Proceedings of the International Workshop on Computing in Civil Engineering, June 19–22, Miami, FL. pp. 405–412.

Narwari, N. 2012a. BIM standardization and wood structures. Proceedings of the International Conference on Computing in Civil Engineering, June 17–20, Clearwater Beach, FL. pp. 293–300.

Nawari, N. O. 2012b. BIM standard in off-site construction. *Journal of Architectural Engineering,* Vol. 18**,** No. 2, pp. 107–113.
Nawari, N .O. 2014. BIM standard: Tensile structures data modeling. *Computing in Civil and Building Engineering*. Proceedings of the International Conference on Computing in Civil and Building Engineering, June 23–25, Orlando, FL. pp. 1166–1173.
Obergriesser, M. and A. Borrmann. 2012. Infrastructural BIM standards–Development of an Information Delivery Manual for the geotechnical infrastructural design and analysis process. eWork and eBusiness in Architecture, Engineering, and Construction. Proceedings of the 9th European Conference on Product and Process Modelling, July 25–27, Reykjavik, Iceland. pp. 581–587.
Sacks, R., A. Kedar, A. Borrmann, L. Ma, D. Singer, and U. Kattel. 2016. SeeBridge information delivery manual (IDM) for next generation bridge inspection. Proceedings of the 33rd International Symposium on Automation and Robotics in Construction, July 18–21, Auburn, AL. pp. 826–834.
See R., J. Karlshoej, and D. Davis. 2012. *An Integrated Process for Delivering IFC Based Data Exchange*. The BLS Consortium and BuildingSMART International. https://bips.dk/files/integrated_idm-mvd_processformats_14_0.pdf.