Iowa Work Zone Data Hub

Final Report
October 2022

Center for Transportation Research and Education

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16. Abstract			
This report details the development and initial rollout of the Iowa Work Zone Data Hub. The primary goal of this project was to develop a statewide system that integrates data from various sources utilizing the Federal Highway Administration (FHWA) Work Zone Activity Data (WZAD) framework and dictionary. The WZAD framework identified 50 different use cases, which involved 27 different stakeholders. The approach for Iowa was to identify a select number of use cases that could be initially implemented or further explored. After identifying essential use cases for implementation in Iowa, all of the use cases within the framework and data elements from the data dictionary were organized in an interactive Excel file. The interactive Excel file was used to prioritize the use cases for Iowa. By focusing on a small number of use cases, the amount of data needed and the number of relevant stakeholders were reduced, making the initial implementation of the statewide work zone data hub more manageable. Two of the top five use cases were implemented in the statewide data hub. A third one was completed by the Iowa Department of Transportation's (DOT's) Advanced Traffic Management System (ATMS), and another was placed on hold based on subsequent agency priorities. The fifth use case was explored, and the project team recommends that the Iowa DOT continue to explore methods of collecting the data for that use case and put the data in a database for future analysis. The expectation is that the Iowa Work Zone Data Hub will continue to be refined as additional use cases are added to the system. The project team expects that a cyclical effort can be done based on priority use cases for the Iowa DOT to continue to grow and expand their work zone data hub.			
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IOWA WORK ZONE DATA HUB

Final Report
October 2022

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ACRONYMS, ABBREVIATIONS, AND INTIALISMS

API	application programming interface
ATMS	Advanced Traffic Management System
CAD	computer-aided design
DMS	dynamic message sign
DOT	department of transportation
FHWA	Federal Highway Administration
HTTP	hypertext transfer protocol
ITS	intelligent transportation system
LRS	linear referencing system
RAMS	Roadway Asset Management System
RCE	resident construction engineer
TCP	Traffic Critical Project
TMC	traffic management center
TTC	temporary traffic control
URL	uniform resource locator
WZAD	Work Zone Activity Data
WZDB	work zone database
WZDI	Work Zone Data Initiative
WZDS	work zone data system
WZDx	Work Zone Data Exchange
WZED	Work Zone Event Data
XML	extensible markup language

EXECUTIVE SUMMARY

Problem Statement

While the Iowa Department of Transportation (DOT) places a high priority on both the safety and efficiency of travel for motorists within work zones across the state, work zone projects can be complex, taking years to plan and design with multiple phases and degrees of traffic disruption. The data associated with a specific work zone can originate in multiple offices and entities, such as planning, design, construction, and operations and also with consultants and contractors.

Background

The Iowa DOT Work Zone Management Service Layer Committee identified the essential need for a common platform to identify, integrate, and access all of the available work zone data from a central hub.

Previous research by this project team identified challenges, established the work zone database (WZDB) without any additional undue burden on field staff or contractors, and developed the database structure by gaining an understanding of the relationships between all of the data frames and data elements (Knickerbocker et al. 2020).

The project team also established a foundation to simplify the efforts to integrate data sources by associating Iowa crash data to the Iowa DOT linear referencing system (LRS) (Knickerbocker et al. 2021). This research demonstrated a simple proof-of-concept architecture that addressed some of the constraints on decision makers and also opened up additional data sets for the Iowa DOT or other researchers to explore without the additional time and effort needed to integrate the data.

Parts of the efforts leading up to the rollout of the work zone data hub were implemented on a limited basis, but not statewide.

Goal and Objectives

The primary goal of this project was to develop and roll out the initial implementation of a statewide system, the Iowa Work Zone Data Hub, that integrates data from various sources utilizing the Federal Highway Administration (FHWA) Work Zone Activity Data (WZAD) framework and dictionary.

The objectives of this project were as follows:

- Develop a method of evaluating use cases in the FHWA WZAD and prioritize use cases for the Iowa DOT

- Evaluate the prioritized use cases on the feasibility to implement
- Begin implementation of the selected case studies, identify the needs to collect the data if they are not currently available, and define the needs to be implemented if the data are not currently available

Project Description and Key Findings

After a literature review to gain a comprehensive understanding of the FHWA framework use cases as well as the associated data, the first step for this project was to identify essential use cases for implementation in Iowa.

The WZAD framework identified 50 different use cases, which involved 27 different stakeholders. Then, all of the use cases within the framework and data elements from the data dictionary were simplified and organized in an interactive Excel file. The interactive Excel file was used to prioritize the use cases in Iowa.

From there, the approach was to identify a select number of use cases that could be initially implemented or further explored. By focusing on a small number of use cases, the amount of data needed and the number of relevant stakeholders were reduced, making the initial implementation of the statewide data hub more manageable.

Two of the top five use cases were implemented in this initial rollout of the statewide data hub. One of the other use cases was completed by Iowa's Advanced Traffic Management System (ATMS), and another was placed on hold based on subsequent agency priorities. The fifth use case was explored, and the project team recommends that the Iowa DOT continue to explore methods of collecting the data for that use case and put these data in a database for future analysis.

Implementation Readiness and Benefits

The Iowa Work Zone Data Hub will provide a connection to work zone activity data serving as documentation and an integration layer that provides access and use of the wide-ranging data sources. The expectation is that the data hub will continue to be refined as additional use cases are added to the system. The project team expects that a cyclical effort can be done based on priority use cases for the Iowa DOT to continue to grow and expand their work zone data hub.

INTRODUCTION

Background

The Iowa Department of Transportation (DOT) places a high priority on both the safety and efficiency of travel for motorists within work zones across the state. Work zone projects can be complex, taking years to plan and design with multiple phases and degrees of traffic disruption. The data associated with a specific work zone can originate in multiple offices and entities, such as planning, design, construction, and operations and also with consultants and contractors.

The Iowa DOT dedicates a diverse team to consider how to enhance work zone performance. A top recommendation of the Work Zone Management Service Layer Committee was data and the essential need for a common platform to identify, integrate, and access all of the available work zone data from a central hub. The Iowa Work Zone Data Hub will provide a connection to work zone activity data serving as documentation and an integration layer that provides access and use of the wide-ranging data sources.

National Efforts

A reference guide or standard was not previously available to provide insight toward digitally describing and communicating the dynamic work activities taking place on US roads and highways. To address this need, the Federal Highway Administration (FHWA) launched the Work Zone Data Initiative (WZDI).

The goals of the initiative were to develop a recommended practice for managing work zone data and to create a consistent language for communicating information on work zone activity across jurisdictional and organizational boundaries. The program's mission was broad and forward-looking, and it has significant implications beyond the traditional stakeholders of highway construction.

The most significant benefit of this effort was expected to include a nationally consistent dictionary and framework for communicating and storing work zone activity data (WZAD) that also provides references to external databases containing related work zone data, e.g., mobility and crash data. WZAD support enhanced work zone management operations within transportation agencies, along with advancing development of WZAD applications that will enable stakeholder use of the data.

The resulting national dictionary content and structure facilitate better harmonization of WZAD for current and future uses, leading to real-time, accurate, and comprehensive data in a standard format that allows for seamless data communications across jurisdictional boundaries.

Two important deliverables from the WZDI included the following:

- **WZAD framework: Framework for Work Zone Activity Data Collection and Management** (Stephens et al. 2020). The framework establishes a standard and consistent approach for collecting, organizing, and communicating work zone information to contractors, neighbor agencies, third-party data consumers, and other key stakeholders. The framework describes the stakeholders, their needs and use cases, and the relevant data content needed to fulfill these needs.

- **WZAD dictionary: Work Zone Activity Data (WZAD) – Data Dictionary Report (**Okunieff et al. 2019). The data dictionary attempts to specify consistent data with respect to meaning and enumerated values, such as assignment of locations (e.g., begin/end locations), temporal states, and impacts.

Project Goal and Summary of Work

The primary goal of the Iowa Work Zone Data Hub project was to develop a system that integrates data from various sources utilizing the WZAD framework and dictionary. A literature review provided a comprehensive understanding of the FHWA framework use cases as well as the associated data content.

From here, the first step for this project was to identify essential use cases for implementation in Iowa. Next, all of the use cases within the framework and data elements from the data dictionary were simplified and organized in an interactive Excel file. The interactive Excel file was used to prioritize the use cases in Iowa with the top use cases to be implemented first in the statewide Iowa Work Zone Data Hub.

The expectation is that the data hub will continue to be refined as additional use cases are added to the system.

Objectives

The objectives of this project were as follows:

- Develop a method of evaluating use cases in the WZAD and prioritize use cases for the Iowa DOT

- Evaluate the prioritized use cases on the feasibility to implement

- Begin implementation of the selected case studies, identify the needs to collect the data if they are not currently available, and define the needs to be implemented if the data are not currently available

PROJECT APPROACH

A data hub is a centralized data exchange system for data storage, definition, integration, and delivery that serves as a single point of access for developers, applications, and users. Data from multiple sources and with various requirements are reconfigured for efficient storage, access, and delivery of information by the data hub.

User Needs and Use Cases

User needs refers to the functions and features of a system desired by its users and stakeholders. A use case is a system engineering term for a user's interaction with a system that technically describes the user needs for data system developers, or for the work zone data system developers on this project. User needs and use cases are fundamental and complementary building blocks for development of system requirements and tests to verify that user needs are satisfied.

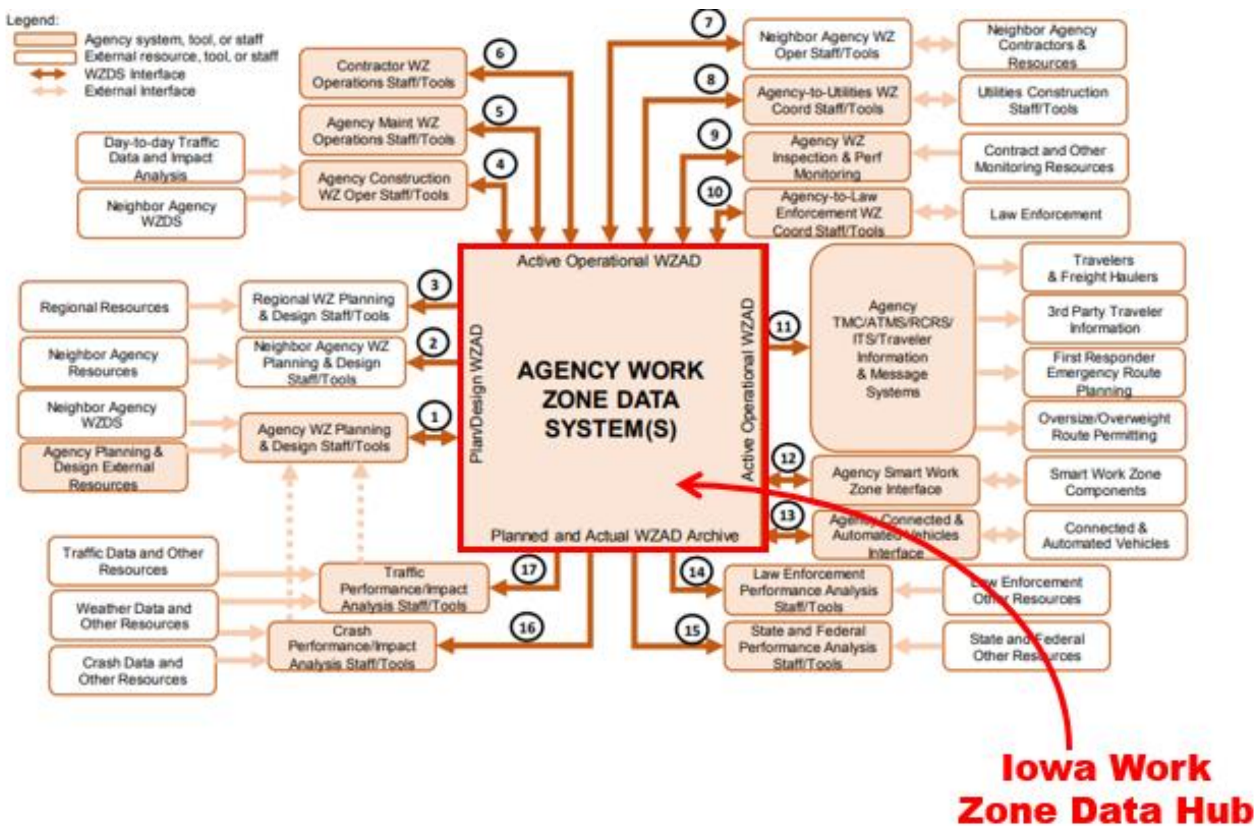
The WZDI conducted a series of stakeholder interviews and meetings to identify stakeholder needs for the WZAD dictionary. From that investigation, the FHWA team identified 27 key user needs for the WZAD dictionary and 50 candidate use cases. When considering implementation and development of a work zone data system (WZDS), agencies may use these user needs and use cases as a starting place to document their own user needs and use cases.

The WZDI lists seven user categories with numerous use cases under each category. The framework adopts a holistic approach including use cases from the planning and design stage of work through to active operations and post-work performance analysis. Figure 1 lists the seven categories of user needs that are focused on the WZDI framework.

CAV=connected and automated vehicle; image based on https://ops.fhwa.dot.gov/publications/fhwahop18083/index.htm

Figure 1. Categories of use cases for work zone data

All of the systems, resources, and staff from relevant stakeholders based on the WZAD framework are shown in Figure 2.



Stephens et al. 2020, FHWA

Figure 2. Work zone data system overview from WZAD framework

The box in the center, highlighted in red, represents the vision of the research team and Iowa DOT for the Iowa Work Zone Data Hub, where all of the connections and interactions with the various data sets are known and available as inputs/outputs to the data hub. The number of stakeholders and data inputs from Figure 2 can be daunting to many agencies, as it appears to be complicated and difficult to connect and coordinate with all of the agencies throughout the work zone lifecycle.

The research team proposed a use case based approach for this project that focuses on addressing a single use case and integrating the data relevant only for that use case. With this approach, as shown in Figure 3, the diagram in Figure 2 can be simplified to show only the relevant data and stakeholders.

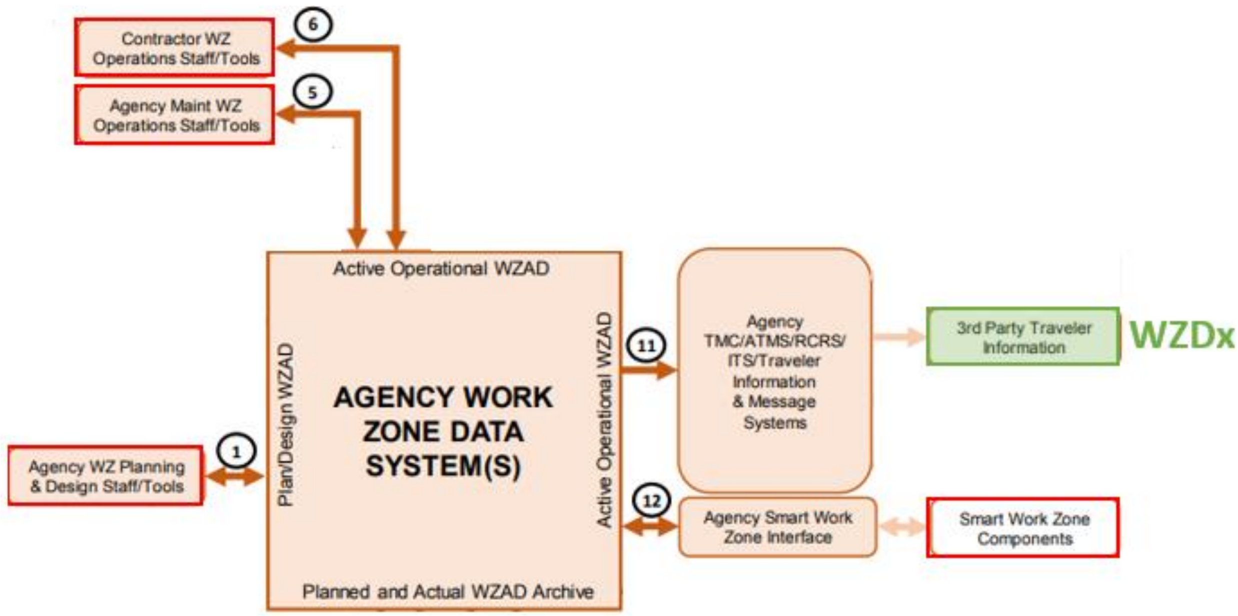


Figure 3. Use case-based approach to simplify implementation

The approach is less daunting as only a handful of data sources must be integrated at a time and once the source mechanism for integrating the data is completed, it can be used for any other use case also utilizing that data source.

Prioritizing Use Cases

In prioritizing and selecting use cases, it can be challenging to work with the WZAD framework and data dictionary due to the vast amount of information available. The documents complement one another by referencing each other, with the WZAD framework listing the use cases and stakeholders, while the data dictionary describes the data necessary to support the use case.

Each use case has detailed information but is difficult to analyze and compare when 50 different use cases are presented. The detailed information can be challenging to summarize in an easy to consume way for prioritization.

To simplify the process, the research team created an Excel file that provided the details for each of the use cases in a table that provided the data in a consumable format. The Excel file allowed the Iowa DOT and research team to easily summarize and compare across use cases. The intention of the spreadsheet tool was not only to summarize the content in the WZAD framework and data dictionary but to also provide Iowa specific information.

The Excel file allowed for entering the priority use cases for the Iowa DOT along with Iowa specific details on data element availability. Once the information was populated, the core use of the Excel file was to help the research team and Iowa DOT select a subset of use cases that could be implemented. Some of the core details included in the Excel file were as follows:

- Elements summarized in the WZAD framework and data dictionary:
  - Use cases
  - Stakeholders
  - Data elements

- Iowa specific inputs:
  - Priority of use case within the Iowa DOT
  - Data availability to support use case

As shown in Figure 4, the Excel file begins with a legend that provides an overview of the details that will be highlighted.

Stakeholder	Legend
Workzone Planning and Coordination	I_A
Design and Engineering	I_B
Workzone Data Systems Development Operations	I_C
Construction Operations Manager and Inspector	I_D
Roadway Maintenance Manager Function	I_E
Utilities Construction Workzone Coordination	I_F
Law Enforcement Coordination	I_G
ATMS Operator Function	I_H
ITS/DMS/Traveler Information Systems	I_I
Congestion and Performance Manager	I_J
Oversize/Overweight	I_K
Regional Partner Agencies	E_A
Construction Contractors	E_B
Third Party Traveler Information (WAZE,Google)	E_C
Utilities	E_D
Law Enforcement	E_E
Travelers, CAV, Freight Haulers	E_F
State and Federal Agencies (DOT)	E_G

Priority	Legend
High	
Medium	
Low	

Life Cycle	Legend
Planning and Design	x
Active Operations	o
Post Workzone Performance	+

Data Availability	Legend
Available	
Available with effort	
Not Available Currently	

Figure 4. Legends from use case prioritization in Excel tool

The legend, on the left, lists all of the stakeholders that are identified as part of the WZAD framework. The intention of the stakeholder legend was to provide coded values (A through K) that could be quickly scanned rather than listing out each stakeholder. The coded value for the stakeholder also includes an indicator of whether the stakeholder is internal (I) or external (E) to the agency as indicated by the first letter of the coded values.

The Priority legend, which is shown top right, is used to indicate the Iowa DOT's preference for each of the use cases and can be viewed as the importance of the use case to the agency at the time. Ultimately, the Iowa DOT classified each use case as either High or Medium priority. As described previously, the WZAD is intended to cover the entire lifecycle with each case study assigned to either planning, active, or post work zone.

Similar to the stakeholders, the Life Cycle legend, center right, provides coded values (×, ○, and +) for quickly comparing across the use cases.

Finally, the legend shown bottom right in Figure 4, provides the classification for whether the data were currently available, whether the data were available but may take some effort to obtain, or whether the data were not currently available or being collected.

After the legends, a sheet that is organized by the seven categories of WZDI use cases for work zone data from Figure 1, summarizes each of the use cases. Users can select a use case, which navigates them to the corresponding sheet with the use case details. The use case details are spread across seven sheets, which align with the seven categories in the WZAD dictionary. Figure 5 shows an example of a use case details sheet.

	A	B	C	D	E	F	G
1	Back to Use Cases				User Needs for Safety and Mobility Performance Meas		
2	Data Elements	Data Availability	Workzone Mobility performance assessment	Workzone Safety performance assessment	Workzone Mitigation Starategy effectiveness assessment	Regional assessments of workzone mobility performance targets	Computing average workzone safety performance measures by region
3	Workzone Life Cycle		+	+	+	+	+
4	Stakeholders		I_A, I_B, I_J	I_A, I_B, I_J	I_A, I_B, E_A	I_A, I_B, E_A	I_A, I_B, E_A
7	Owner Agency		1	2			5
9	Contractor / Subcontractor		1	2			5
12	Actual Number of Phases		1	2			5
15	Project ID		1	2	3	4	5
16	Event ID		1	2	3	4	5
17	Subevent ID		1	2	3	4	5
23	Name of the Roadway where event/subevent is located		1	2	3	4	5
24	Roadway classification of roadway where event/subevent is		1	2	3	4	5
25	Facility type of roadway where event/subevent is located		1	2	3	4	5
26	Direction of travel of event/subevent		1	2	3	4	5
29	Actual begin location of event/subevent		1	2			5
30	Actual end location of event/subevent		1	2			5
43	Actual start date/time of event/subevent		1	2			5
44	Actual end date/time of event/subevent		1	2			5
45	Status		1	2			5
56	Actual geometrics associated with each event/subevent		1	2			5
57	Actual traffic control device(s) associated with each		1	2			5
98							

Figure 5. Use case details sheet for Safety and Mobility Performance Measurement

The details on these sheets allow users to quickly see and compare across use cases and only focus on relevant lifecycle stages or stakeholders.

Along the Data Elements row 2 is a list of all the use cases, which may range in these sheets from three to 12 use case columns, depending on the category, which is listed in the top right corner of row 1. (This example in Figure 5 shows the details sheet for the Safety and Mobility Performance Measurement category.)

The colors of the use case column headings in the Data Elements row 2 indicate the priority assigned to each use case (with red for high, blue for medium, and yellow for low) based on a review by the research team and the Iowa DOT.

The Workzone Life Cycle row 3 identifies where the use case is in the work zone lifecycle by coded symbol value (×, ○, or +), followed by the relevant stakeholders in row 4 under that, which are coded based on the legend previously shown in Figure 4.

Under the Stakeholders row 4, column A lists the work zone attributes that were identified in the WZAD dictionary on each details sheet. In total, 80 attributes were listed and are organized by organization, location, time, activity/event, and metadata. The next column (B) identifies whether the data is available for Iowa (with green indicating the data was easily available, yellow indicating the data was available with effort, and red indicating the data was not currently available).

In the main body of the matrix are number values associated with the given use case. The presence of the value indicate that those attributes were identified in the framework as being required or necessary for the given use case. This can be viewed as the minimum data elements needed to help facilitate the use case. By organizing the data in this way, users can easily compare across the use cases to see which attributes are common across multiple use cases. Additionally, filters can be applied on each of the use cases to show only the relevant attributes that are necessary for the use case.

The research team then went through all of the use cases and identified which use cases were feasible based on the data currently available. These use cases were deemed lower hanging items that could easily be accomplished based on the availability of data as well as being a priority for the agency. In addition to those use cases, some high priority use cases for the Iowa DOT that did not currently have the data available were also included.

The intention of prioritizing all of these use cases was to get some effort started to begin collecting or identifying a method of collection due to the priority of the use case. The process resulted in the 50 use cases being reduced down to 12. The short list of use cases for possible implementation in Iowa were as follows:

- Corridor Mobility Impact Assessment
- Work Zone Safety Performance Analysis
- Work Zone Mobility Performance Analysis
- Oversize/Overweight Vehicle Route Coordination
- Agency Maintenance Contract Coordination
- Work Zone Mitigation Strategy Effectiveness Assessment
- Work Zone Plan Dissemination to Third-Party Data Providers
- Advanced and Real-Time Intelligent Transportation System (ITS) and Dynamic Message Sign (DMS) Detour Traveler Information
- Weather Impacts Assessment
- Monitor Law Enforcement Use on Projects
- Agency Project Initiation and Planning Temporary Traffic Control (TTC) Coordination
- Adjustment to Smart Work Zone Deployment

With a smaller number of use cases, a more detailed summary was developed and presented to the Iowa DOT. The summary included the description of the use case, an example of how the use case could be implemented, a summary of the data available, and the research team's analysis of the outcomes and effort to achieve the data needs for each use case.

Upon completion of the summaries, a survey was sent to the relevant Iowa DOT staff for them to prioritize the use cases individually. The survey results were combined, which resulted in the prioritized list of use cases, as shown in Table 1.

Table 1. Final prioritized use cases after survey

Rank	Use Case
1	Work Zone Mobility Performance Analysis
2	Agency Project Initiation and Planning TTC Coordination
3	Work Zone Plan Dissemination to Third-Party Data Providers
4	Work Zone Safety Performance Analysis
5	Corridor Mobility Impact Assessment
6	Work Zone Mitigation Strategy Effectiveness Assessment
7	Weather Impacts Assessment
8	Agency Maintenance Contract Coordination
9	Advanced and Real-Time ITS and DMS Detour Traveler Information
10	Oversize/Overweight Vehicle Route Coordination
11	Adjustment to Smart Work Zone Deployment
12	Monitor Law Enforcement Use on Projects

This diverse set of use cases were selected to either improve or formalize current procedures or to develop new ways of collecting data to achieve a use case. With the use cases prioritized, the top five use cases were selected, as follows, as a focus for initial integration into the Iowa Work Zone Data Hub:

- Work Zone Mobility Performance Analysis
- Agency Project Initiation and Planning TTC Coordination
- Work Zone Plan Dissemination to Third-Party Data Providers (completed by Iowa's Advanced Traffic Management System [ATMS])
- Work Zone Safety Performance Analysis
- Corridor Mobility Impact Assessment (on hold based on subsequent agency priorities)

During the implementation phase of the project, it was identified that one of the use cases was being implemented by another bureau within the Iowa DOT, and the priorities for another use case by the Iowa DOT changed. Because of these changes, only three of the use cases were selected to be implemented or further explored.

The remaining nine of the short listed prioritized use cases can be used in future work plans for the Iowa DOT. Because the three use cases for implementation all varied in their level of maturation within the Iowa DOT, each use case had different requirements and levels of completion. Two use cases could be fully implemented and stored according to the WZAD dictionary while one could only work toward making the needed data available.

CASE STUDY IMPLEMENTATION

This chapter details the initial implementation efforts for the final three selected use cases including all work items and the level of completion.

Iowa DOT Case Studies

After the use case prioritization described in the previous chapter, the following three use cases were selected for implementation:

- Work Zone Mobility Performance Analysis
- Work Zone Safety Performance Analysis
- Agency Project Initiation and Planning TTC Coordination

The first two use cases align with current processes that exist within the Iowa DOT but are completed for only a small percentage of the work zones statewide. The implementation for these two use cases as part of the work zone data hub expand the current effort to include all work zones that are currently archived statewide based on Iowa’s current work zone data.

The last use case is an initial implementation of collecting TTC data before a work zone is deployed so that the data can be more readily available for future work zone analysis and planning.

The sections that follow are dedicated to each of the use cases to describe the efforts that were completed to implement each of them, including data integration, database development, and backend processing.

Work Zone Mobility Performance Analysis

The work zone mobility performance use case is a high priority for the Iowa DOT as this has been a primary output of their Traffic Critical Project (TCP) program. The TCP program includes daily and weekly mobility performance measures for a select number of work zones that were identified based on their potential impact to traffic. The mobility performance measures for the TCP program allow for the performance of a work zone to be tracked regularly and to go back historically and identify any mobility issues.

The current mobility performance measures are based only on traffic sensor data using side-fire radars. The issue with the current approach to monitor only TCP work zones is that mobility issues may not always be identified before a project is let.

Without performance monitoring, larger mobility issues that develop may not be identified until a high profile crash or multiple crashes occur. The ability to quantify and monitor mobility performance on a statewide level will potentially allow for quicker identification of mobility issues by the Iowa DOT.

The use of probe data for TCP work zone performance monitoring was not currently available but was being developed concurrently with this project. The coordination of the two projects will allow for the probe-based mobility performance measures to be deployed on a larger scale than initially planned.

The following section describes how mobility performance measures for sensors and probe data were implemented as part of the work zone data hub.

To begin, the following provides details of the use case as described from the WZAD framework:

WZAD Category: Safety and Mobility Performance Measurement

WZAD Description: Agency analysis of individual work zone mobility performance

WZAD Example Use Cases: Agencies would like to compute delay and queuing metrics occurring during an active project and/or after the project is complete for various periods (e.g., during peak periods, during work activity periods, during times of short-term lane closures, and during full weekend road closures). An agency could also desire to compare estimated measures developed during impact analyses to actual measures occurring during the work zone to assess the accuracy quality of the initial estimates.

As suggested, the WZAD architecture was the starting place for the research team to identify the data elements needed for the work zone data hub. Table 2 includes all of the data elements identified in the WZAD data dictionary and the availability of the data in Iowa using the same legend as the Excel file, where green represents data being available, yellow indicates data are available with effort, and red indicates the data are not currently collected.

Table 2. Data elements for work zone mobility performance use case

Use Category Data	Data Availability
Owner Agency	
Expected Number of Phases	
Project ID	
Event ID	
Subevent ID	
Name of the Roadway where event/subevent is located	
Roadway classification of roadway where event/subevent is located	
Facility type of roadway where event/subevent is located	
Direction of travel of event/subevent	
Planned begin location of event/subevent	
Planned end location of event/subevent	
Planned start date/time of event/subevent	
Planned end date/time of event/subevent	
Status	
Expected geometrics associated with each event/subevent	
Expected traffic control device(s) associated with each event/subevent	

As discussed in more detail below, a parallel project was completed that archived the work zone details, which made a majority of the data elements available or provided a potential placeholder for any missing data element for their future data collection.

In addition to the work zone data details, the WZAD dictionary (WZDD) identifies a data concept on Expected Effect on Travel Time/Delay/Queuing but does not list any schema, data frames, or data elements. Because of this, existing efforts by the research team that calculate mobility performance measures for work zones for the TCP program using sensor and probe data were utilized. The outputs of those were modified to include a work zone identifier from the WZAD that can be related back to the work zone data that is archived based on the data in Table 2.

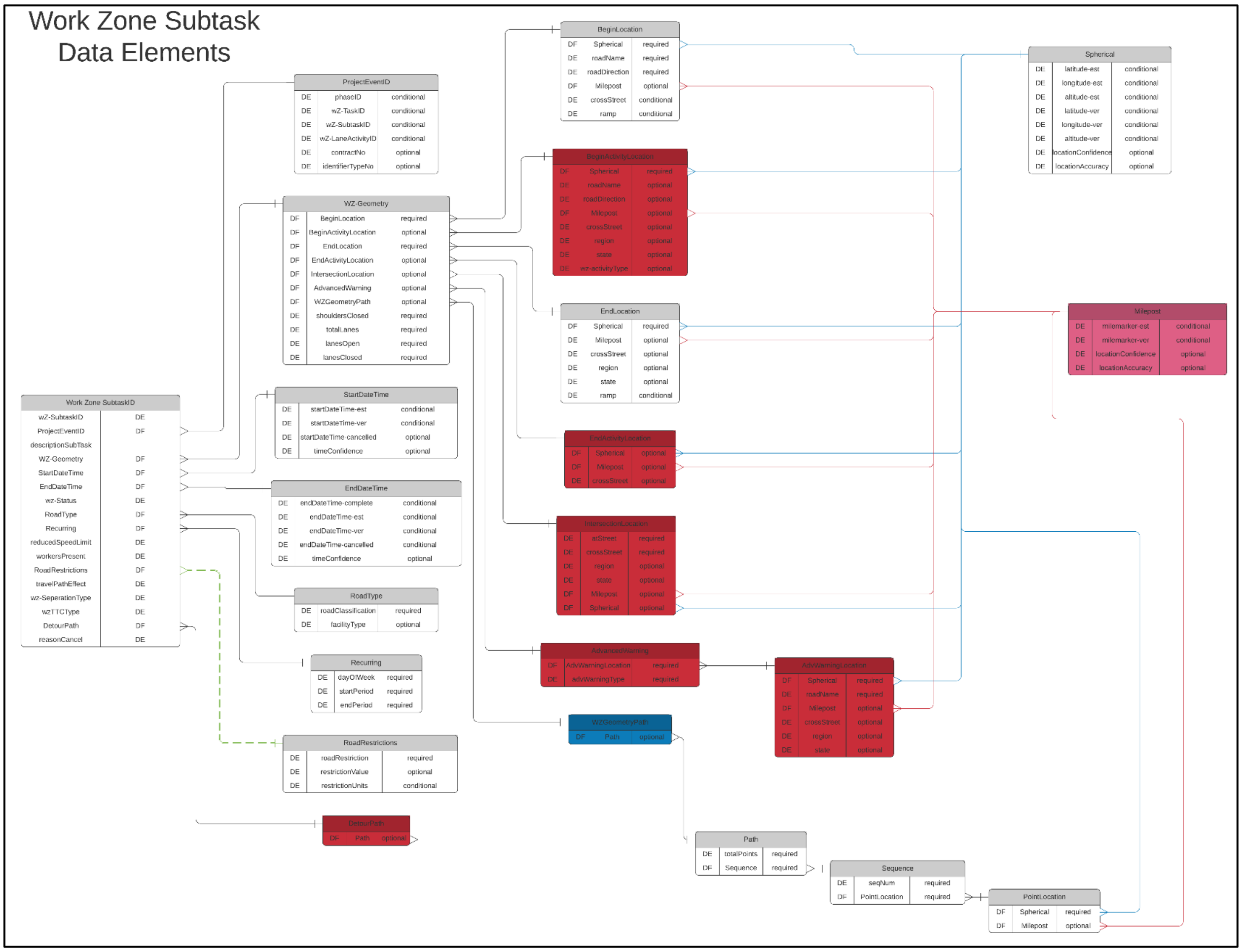
Integrating Data Sources – Mobility Use Case

The following sections describe each of the data sources used in the mobility use case as well as the method for integrating the data sources.

Work Zone Data

A parallel project (Knickerbocker et al. 2020) completed by the research team that also followed the WZAD concepts developed a work zone database (WZDB) by integrating the planned 511 work zone data with smart arrow boards that are currently deployed in Iowa. The archived data provides an initial database structure for planned work zones in 511 but also verifies work zone locations and times based on the available smart arrow board data. The availability of these data provide confidence for users on the accuracy of the data location and duration.

As mentioned, the WZDB followed the WZAD framework and dictionary as shown in Figure 6.



Knickerbocker et al. 2020

Figure 6. Entity relationship diagram of WZDB

All of the attributes listed in Table 2 are available in the WZDB with some additional attributes that are necessary for integration in Iowa. The SubTask table contains a majority of the details about the work zone. Each subtask represents an individual direction for a work zone, which can be aggregated up to the overall work zone based on other attribute fields. For example, if a work zone is closing a lane in both directions of travel, it will have two subtask records: one for direction 1 and one for direction 2. An identifier in the database allows for the two subtasks to be associated to each other for the overall work zone impacts. The wZ-SubtaskID is used as the unique identifier and is the primary method of relating the WZDB to the mobility performance measure outputs.

The WZDB is currently populated based on a process that checks the 511 and arrow board data every 5 minutes. If any additions or changes to the work zone are identified, the database is updated with those changes. During the process, the data are conflated to the Iowa DOT linear referencing system (LRS), which allows for easier data integration across the agency. The final process results in a populated work zone database that includes verified coordinates and times, which provide confidence to users on the accuracy of the work zone data.

The process has been running since late 2020 and includes archived work zone data since that time. Based on this flow of the data, it is expected that the data that are available at the end of the day accurately represent the work zone data for that day.

The Iowa DOT LRS is a critical component that simplifies the data integration needs for this use case as well as many others. A combination of the route identifier and start/end measure values within the WZDB allows the work zone to easily be integrated with other data sources. Any other data that are needed to support this use case, including the sensor locations and probe data segment locations, can simply be related to the common network of the LRS. Once all data are related to the same network, the data can then be easily associated to each individual work zone. A combination of the route identifier and start/end measure values facilitate the work zone data being easily integrated with other data sources.

Sensor Data

The Center for Transportation Research and Education at Iowa State University currently archives all traffic sensor data in Iowa for more than 300 sensors. The sensor are side-fire radar systems, which can collect each individual lane of data. The Iowa DOT has a combination of permanent sensors deployed across the state as well as work zone sensors. The sensor data provide aggregated speeds for each individual lane of the roadway every 20 or 60 seconds depending on the type of sensor. Figure 7 shows a map of the permanent and temporary sensors in Iowa as of July 2022.

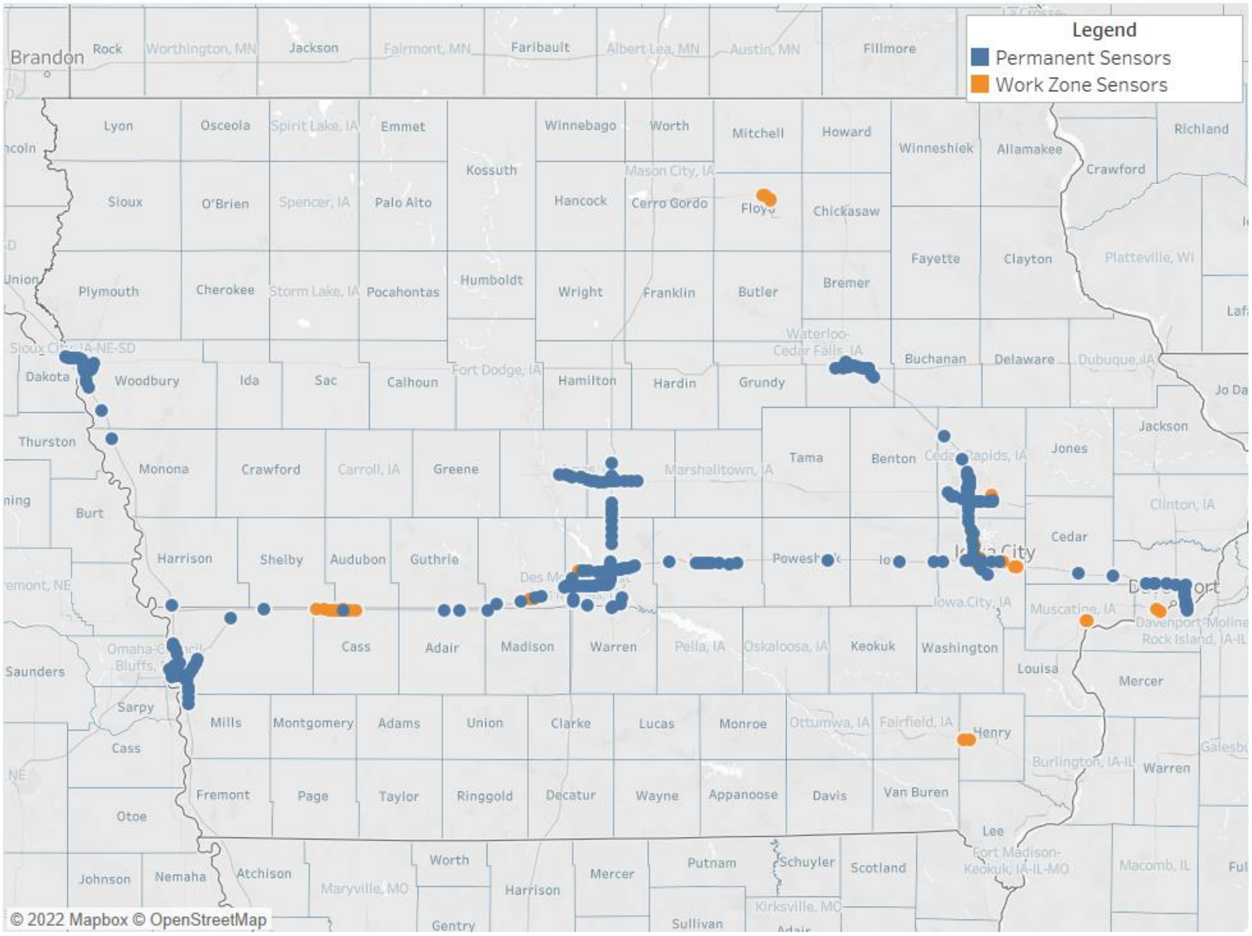


Figure 7. Sensors in Iowa in July 2022

The traffic data from the sensors are regularly collected as described above but the location information for the sensors includes less frequent updates. The sensor location data are downloaded daily and then summarized monthly for historical tracking.

To support the mobility use case, the Iowa DOT LRS is utilized to identify if any sensors are located within the work zone extents. Although the sensors are associated with the Iowa DOT LRS within the ATMS, those data are not available as part of the location information data feed. The LRS details are also limited in the ATMS as sensors are only associated with a single direction of travel in the LRS. Because each work zone in the WZDB represents only a single direction of travel, the sensors must be related to both centerlines if the work zone is on a divided roadway. This ensures that the sensors in the given direction of travel of the work zone are available and accurately associated to the work zone. Because of this, a separate process was developed that relates the sensors to the LRS.

The first step in the process to relate the sensors to the LRS was to download the sensor location information from the application programming interface (API) available from the ATMS. The API includes the latest sensor data available within the ATMS. Because the data are not frequently updated, the process was developed to only run once per day to obtain a snapshot of the sensors available during that day.

From the API, the information obtained from each sensor include the latitude, longitude, device-id, device name, link-direction, and link-name. The device name and device-id are used to extract the relevant traffic data for the sensor. The link-direction and link-name represent the direction of the roadway and the name of the roadway on which the sensor is located within the ATMS. This information is utilized in the conflation to the LRS to ensure the correct roadway was selected.

With the sensor location information, the sensors are conflated to the Iowa DOT LRS to obtain the route id and measure values. The sensor is associated to the closest roadway within 50 meters and then ran through a route dominance algorithm to fetch the most dominant route for the given location. The dominant route is necessary, as this is the route the work zones would be related to as well as all of the other relevant agency data within Iowa.

After the initial conflation, validation checks are made to ensure the sensor is associated to the correct route id in the LRS. The location information provided by each sensor represents the actual location of the physical sensor but the device typically collects both directions of travel. Since each individual lane is included in the location information, a majority of the sensors are assigned to the incorrect direction of travel. As depicted in Figure 8, the initial conflation of the sensor data is represented by the blue arrow showing that the physical location of DMDS82 is conflated to S001910035N, which represents I-35 North.

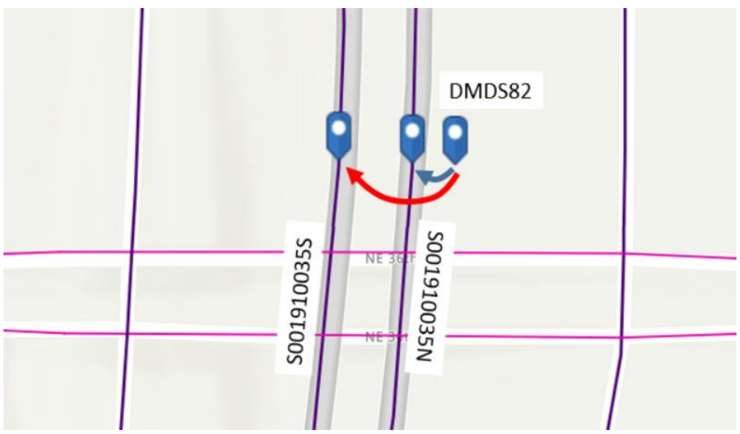


Figure 8. Sensor data conflation to LRS

For all of the northbound lanes of the sensor, the process stops as the sensor location is assigned to the correct direction of travel. For the southbound lanes of the sensor, the direction is identified as a mismatch and re-conflated to the network, as shown by the red arrow in Figure 8. During the re-conflation process, the correct route id is defined so that it conflates correctly to the route. In the Figure 8 example, the route id is defined in the re-conflation as S001910035S by simply changing the last letter in the original conflated route from N to S given that is the direction of the sensor. Any mismatching sensors after the completion of these steps are flagged and sent to the ATMS for correction.

Probe Data

Similar to the sensors, probe data are archived by the research team across the entire state. The probe data are purchased by the Iowa DOT from a third party, which provides data on all state roadways as well as other high priority roadways. The probe data provides speed data aggregated every minute.

The probe data are summarized by segments, which are approximately one mile in length. The segmentation used by the third party is updated two times a year and does not need to be regularly archived like the sensor data. Similar to the sensor data, the LRS is the primary method of relating the probe data segments to the work zones in the WZDB.

The research team utilized an existing process that already associated probe data segments to the LRS and was developed by the research team and the Iowa DOT. The process takes all of the verticies of the segment and conflates them to the LRS data based on the closest route before running. Each of the points are then run through a route dominance algorithm to fetch the most dominant route for the location.

To identify on which route the segment is located, the route id that is most common among all of the vertices is selected. From there, the minimum and maximum measure values across all of the vertices are used as the begin and end measures.

Each probe data segment represents the speed for a single direction of travel and is conflated to the centerline for the given direction of travel on divided roadways. This is the desired output, so no additional processing of the data is needed.

Roadway Asset Management System (RAMS)/Linear Referencing System (LRS)

As described in the previous sections, the LRS is a critical component to the integration of the work zone and mobility data. By conflating all data to a common network, it simplifies the process of relating a sensor or segment to a work zone and reduces the number of assumptions that would need to be made otherwise. In addition to utilizing the network, other attributes are extracted from the Roadway Asset Management System (RAMS), which is the asset management system used in Iowa that is built on the LRS.

Attributes currently extracted include the average annual daily traffic (AADT) and speed limit. These attributes are necessary for accurately in calculating the mobility performance measures, but other attributes within the RAMS could also be used for future enhancements.

Database Structure – Mobility Use Case

The WZAD framework and dictionary do not currently define the outputs for the mobility performance measures. Because of this, the research team utilized existing outputs and database structures. The following describes the database structure of the outputs for the sensor-based mobility performance measure and the probe data-based mobility performance measures.

Sensor Database Structure

Table 3 provides an overview of the fields available within the sensor-based output for the mobility performance measures use case.

Table 3. Database structure for sensor mobility performance

Field Name	Field Description	Units
Date	Date of mobility performance measures	
wZ-SubtaskID	Work zone unique identifier in WZDB	
Direction	Direction of travel for work zone	
time_weighted_queue_length	Time weighted queue length	minutes
number_of_events	Number of events	events
number_of_daytime_events	Number of daytime events	events
average_duration_of_each_event	Average duration of each event	minutes
median_duration_of_each_event	Median duration of each event	minutes
average_queue_length	Average queue length	miles
average_maximum_queue_length_of_each_event	Average maximum queue length of each event	miles
median_maximum_queue_length_of_each_event	Median maximum queue length of each event	miles
max_maximum_queue_length_of_each_event	Max maximum queue length of each event	miles
percentage_of_queue_greater_than_1_mile	Percentage of queue >1 mile	percentage
amount_of_traffic_that_encounters_a_queue	Amount of traffic that encounters a queue	vehicles
total_traffic	Total Traffic	vehicles
percentage_of_traffic_that_encounters_a_queue	Percentage of traffic that encounters a queue	percentage
percentage_of_time_that_encounters_a_queue	Percentage of time that encounters a queue	percentage
total_delay	Total vehicle hours of delay	vehicle-hours
average_delay_per_vehicle	Average vehicle hours of delay per vehicle	vehicle-hours
maximum_delay	Maximum delay	minutes
total_delay_when_queue_is_present	Total vehicle hours of delay when queue is present	vehicle-minutes
percentage_of_delay_caused_by_queue	Percentage of delay caused by queue	percentage
avg_delay_when_queue_is_present	Average vehicles hours of delay per vehicle when queue is present	vehicle-minutes
percentile_95_of_delay_for_all_times(min)	95th percentile of delay for all times	minutes
percentile_95_of_delay_when_there_is_queue(min)	95th percentile of delay when there is a queue	minutes
total_time_with_queue	Total time with a queue	minutes

Field Name	Field Description	Units
maximum_delay_for_an_event	Maximum vehicle hours of delay for an event	vehicle-hours
maximum_total_delay_per_minute	Maximum vehicle hours of delay per minute	vehicle-hours

The data represent the mobility performance measures for a single day and can be aggregated up to higher level of aggregation if needed. Each record has an associated wZ-SubtaskID, which can be related back to a given work zone including all of the relevant attributes for that work zone. Additional descriptions of each of the data attributes can be found in the appendix to this report.

Probe Database Structure

Table 4 provides an overview of the fields available within the probe-based output for the mobility performance measures use case.

Table 4. Database structure for probe mobility performance

Field Name	Field Description	Units
date	Date of mobility performance measures	
wz-SubTaskID	Work zone unique identifier in WZDB	
direction	Direction of travel for work zone	
Delay	Delay	minutes
TTReliability	Travel time reliability	
SpeedDeficit	Speed deficit	minutes
FreeflowTT	Free-flow travel time	minutes
Actual_traveltime	Actual travel time	minutes
Speed_15thpercentile	15th percentile speed	miles per hour
Avg_speed	Average speed	miles per hour
Avg_reference	Average reference speed	miles per hour
Congested_speed	Minutes of congestion (speed<45)	minutes
Congested_speed_miles	Mile-Minutes of congestions (speed<45)	mile-minutes
Queue_speed	Minutes of queue (speed<15)	minutes
Queue_speed_miles	Mile-Minutes of queue (speed<15)	mile-minutes

The data represent the mobility performance measures for a single day and can be aggregated up to higher level of aggregation if needed. The number of calculations using probe data is more limited due to no volume data being available. Those limitations are overcome given that the data are available statewide and can be used for a larger range of work zones that don't have sensors. Similar to the sensor data, each record has an associated wZ-SubtaskID, which can be related back to a given work zone including all of the relevant attributes for that work zone.

Data Processing – Mobility Use Case

With the data inputs defined and processed as well as the output database defined, the process of calculating the work zone mobility performance measures use case could be developed. The following sections describe the process that was implemented to calculate the work zone mobility performance measures.

Sensor Mobility Performance Process

An overview of the data inputs and processing of the data to support the sensor mobility performance process is shown in Figure 9.

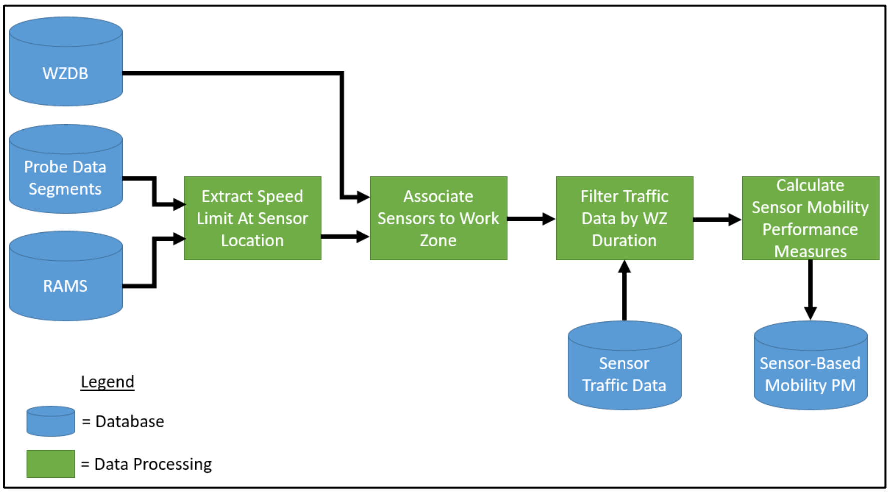


Figure 9. Sensor-based performance measure process

The process is set up to run once per day and to calculate the sensor mobility performance measures for the previous day for any work zone data that were archived in the WZDB. This is possible based on the assumption that all of the data are complete and up to date by the end of the day. This assumption is valid given all of the data are based on real-time streaming data that are being updated at a frequency of no more than 5 minutes.

The process begins by connecting to the sensor location information previously described and extracting the speed limit at the location of each sensor. The sensor data have a route id and measure value, which are then used to identify the corresponding speed limit in the RAMS based on the LRS values. The speed limit information is needed for the sensor as a way to calculate delay for the performance measures, assuming that the speed limit is the baseline for the travel time through the work zone.

After the sensor location information is updated, the sensors are associated to the corresponding work zones. The WZDB is filtered to retain only work zones that were active the previous day. The previous day is defined as whether the day fell between the start and end dates for the work zone in the WZDB. Any historical or planned work zones would be removed from the analysis.

The wZ-SubtaskID is used as the unique identifier for each work zone for the remainder of the data processing.

With the active work zones, the route id and begin/end measure values are used to find the corresponding sensors that are located along the same route and located between those measure values. Since each work zone represents a single direction of travel, for divided roadways, no additional processing is necessary given that each sensor is only associated to the direction in which the lane data are collected. For undivided roadways, only the sensors with the direction matching the begin location direction in the WZDB are retained.

With the sensors assigned to the work zones, the sensor data are then sorted based on their measure values along the LRS. Using the measure values, the distances between sensors are calculated to get an approximate representation of the distance along the work zone that each sensor represents. This is necessary to calculate travel time estimates given that the sensors provide only point speeds. The distances are found by taking the distance to the next upstream sensor and to the downstream sensor and then dividing by two. This is done so that each sensor represents half the distance of the roadway between the next sensor upstream and the last sensor downstream. If no upstream or downstream sensors are available, only the distance to the next sensor is considered. If only a single sensor is associated to a work zone (no upstream or downstream sensors), it is assumed that the sensor represents a 1 mile portion of the work zone.

The sensor data are now in their final form and are used as the input for the sensor mobility performance measure calculations. Again, the mobility performance measure calculations use an existing process from the research team that calculates the mobility performance measures for TCP work zones.

The sensor location information is used to filter the actual traffic data from the sensor data for the previous day. The work zone start and end times are then also used to filter the traffic data to only the relevant time periods for the work zone duration. This ensures that only data from the time the work zone is active is considered as part of the calculations.

The sensor mobility performance measures are then calculated for each wZ-SubtaskID and output to a database specific to the sensor-based mobility performance measures.

Probe Mobility Performance Process

An overview of the data inputs and processing of the data to support the probe mobility performance process is shown in Figure 10.

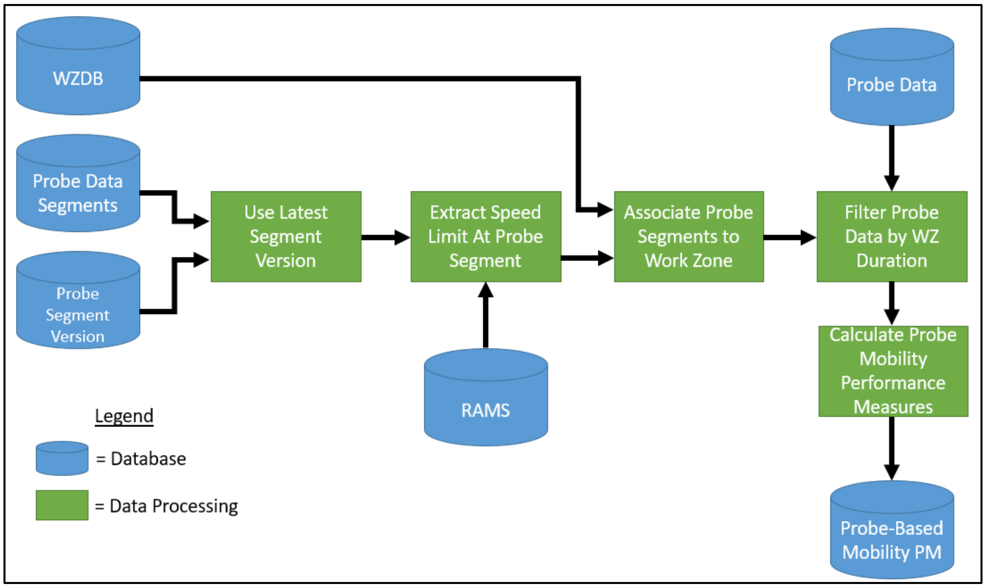


Figure 10. Probe-based mobility performance measure process

The process is similar to that for the sensor data with slight changes to the segment selection due to the versioning of the segmentation. The process is set up to run once per day and to calculate the probe mobility performance measures for the previous day for any work zone data that were archived in the WZDB. This is again possible based on the assumption that all of the data are complete and up to date by the end of the day, which is valid given that all of the data are based on real-time streaming data that are updated at a frequency of no more than 5 minutes.

The process begins by connecting to the probe data segments and a database that contains the version history for the probe data. The probe data segmentation is updated twice a year, which the version database tracks based on a start and end date for each version. All probe data segments, regardless of version, are located in the segmentation database, which includes the route and begin/end measure values for each segment. When the data are added to the database, the version of the segmentation is added as a field that can then be used in coordination with the version database.

The first step in the process filters the version database table based on the previous day's date to find the current probe data segment version. With the correct version identified, this information is then used to filter the probe data segments database to keep only the segments using the current version.

With the current segments selected, the speed limit data for each segment, which are used to calculate delay for the performance measures, are extracted. The speed limit data are based on the information available in the RAMS. Both the segment and speed limit data are linear features, but to simplify the data integration, only the start points of the probe data segment are utilized. The route id and measure value for the start location of each segment is used to identify the corresponding speed limit in the RAMS based on the LRS values. Only the start locations are used to avoid replicating segments that had a speed limit change in the middle of the segment. It is expected that this would have minimal impact on the performance measures, as most segments are less than one mile in length, so any speed changes along a segment would only be incorrectly represented for a short section of the roadway.

The next step in the process assigns probe data segments to each corresponding work zone. Similar to the sensor data, the WZDB is filtered to retain only work zones that were active the previous day based on whether or not the previous day fell between the start and end dates for the work zone. Any historical or planned work zones are then removed from the analysis. The wZ-SubtaskID is used as the unique identifier for each work zone for the remainder of the data processing.

To identify the segments in the work zone, a linear overlay between the two linear features could be completed. By performing a linear overlay, any segments at the begin or end of the work zone would be shortened to either start or stop at the begin/end location. This would then alter the original length of the segment.

The research team instead decided to keep the entire segment due to the segments only being one mile in length and the fact that the speeds are representative of the entire segment and not just the portion of the segment in the work zone. To achieve this, a simple join between the WZDB and probe data segments was used, where the route ids had to match and the begin or end measure values of the segment fell between the work zone extent measure values.

Similar to the sensors, for divided roadways, no additional processing is necessary given the work zone and probe data segments both represent a single direction of travel. For undivided roadways, only the segments with the direction matching the begin location direction in the WZDB are retained.

With the probe data segments associated to each work zone, the mobility performance measure calculations are completed. The probe segments associated to the work zones will be used to filter the probe data, which are archived every minute for the previous day. The work zone start and end times will then also be used to filter the probe data to only the relevant time periods for the work zone duration. This ensures that only the time periods for which the work zone was active are considered as part of the performance measures.

The probe mobility performance measures will then be calculated for each wZ-SubtaskID and output to a database specific to the probe-based mobility performance measures. As previously mentioned, the mobility performance measure calculations were developed through another effort by the research team.

Work Zone Safety Performance Analysis

Improving work zone safety is another high priority for the Iowa DOT with multiple efforts being implemented to identify and associate crashes to work zones. For example, a manual effort is being completed by the Iowa DOT to review each coded work zone crash and associate it to a known work zone.

In addition to that effort, a limited effort is being conducted for the TCP work zones, where any crash within 500 ft of the estimated work zone extents are identified and summarized. This use case will allow for the process that is currently being implemented for the TCP work zones to be expanded statewide for any work zone that is being archived through 511 and smart arrow boards. The output will allow for crashes to be associated with individual work zones.

Multiple benefits are expected in associating crashes with specific work zones. The first is the ability for more detailed tracking of crashes within a given work zone that is not typically quantified by the Iowa DOT unless a large number of crashes occur. Another benefit is the ability in the future to associate attributes, such as temporary traffic control standards, lane narrowing, or work activity, to a given work zone for a more detailed analysis of crashes in work zones. The next section describes how safety performance measures were implemented as part of the Iowa Work Zone Data Hub.

To begin, the following provides details of the use case as described in the WZAD framework:

WZAD Category: Safety and Mobility Performance Measurement

WZAD Description: Agency analysis of individual work zone safety performance

WZAD Example Use Cases: Agencies would like to determine the change in crash risk that occurs during an active project and/or during a past project for various periods. The determination could include comparing the estimated safety measure computed during impact analyses to actual measures occurring during the work zone to assess the quality of the initial estimates.

As suggested, the WZAD architecture was the starting place for the research team to identify the data elements needed for the work zone data hub. Table 5 includes all of the data elements identified in the WZAD dictionary and the availability of the data in Iowa.

Table 5. Data elements for work zone safety performance use case

Use Category Data	Data Availability
Owner Agency	
Expected Number of Phases	
Project ID	
Event ID	
Subevent ID	
Name of the Roadway where event/subevent is located	
Roadway classification of roadway where event/subevent is located	
Facility type of roadway where event/subevent is located	
Direction of travel of event/subevent	
Planned begin location of event/subevent	
Planned end location of event/subevent	
Planned start date/time of event/subevent	
Planned end date/time of event/subevent	
Status	

Similar to the mobility performance use case, the WZDB completed through a parallel project made a majority of the data elements available for this effort.

Integrating Data Sources – Safety Use Case

The following sections describe each of the data sources used in the safety performance use case as well as the methods for integrating the data sources.

Work Zone Data

As described for the mobility performance use case, a parallel project was completed by the research team that also followed the WZAD and developed a WZDB. This same database is used as input for the safety performance use case. Additional details about the work zone data can be found in the Integrating Data Sources – Mobility Use Case section of this report.

Crash Data

Iowa has a robust crash data management program with more than 95% of crashes electronically submitted (https://iowadot.gov/tracs). Almost all of the crashes are also geo-located and submitted on a timely basis. The Iowa DOT downloads crash data, which includes data on any crashes that have been submitted to the DOT, on a weekly basis. With a large portion of the crash data being available within days or weeks, the crash data can be used for more near-term analysis and tracking of work zone crashes.

As with the other data sources, the method of integrating the crash data with the work zone data is through the use of the Iowa DOT's LRS. The program that is used to submit the crash data in Iowa is currently in the process of migrating from an older roadway network to the Iowa DOT's LRS network. This is a significant improvement because it allows for route id and measure values to be collected as part of the crash data, which will simplify the integration with other data sources.

This update is being gradually rolled out to agencies, which means that not all of the crash data currently have a route id and measure value. To supplement this, a process developed for conflating crashes to the LRS through a separate project (Knickerbocker et al. 2021) completed by the Center for Transportation Research and Education at Iowa State University was utilized. The process developed as part of that effort conflates the crash data to the LRS and then uses a combination of variables from the crash data, including speed limit and direction, to select the route id that is most comparable to that for the crash data (matching speed limits, matching direction of travel, etc.). A combination of this process and the LRS values directly collected for a subset of crashes is used to integrate the crash data with the work zone data.

The crash data contain a variety of fields for which the data are collected as part of the crash investigation, including a field indicating whether or not the crash was work zone related. The research team decided to not use this field to filter the crash data to associate to the work zones due to it not being currently required during crash data submission. Through working with the data in the past, the research team regularly identifies and provides feedback to the Iowa DOT on crashes that occur within work zones but are not coded as work zone related. By including all crashes, it includes many crashes that are not work zone related but can help in identifying some that should be coded as work zone related. It is expected that, as the accuracy of the WZDB improves, it will be a better identifier of whether a work zone was present at the time of the crash than the information submitted in crash reports.

Roadway Asset Management System (RAMS)/Linear Referencing System (LRS)

Although not directly utilized as with the mobility performance use case, the LRS is a critical component to the integration of the work zone and crash data. By conflating all data to a common network, it simplifies the process of relating crashes to a work zone. It also reduces the number of assumptions that would need to be made for a spatial only analysis. No other data from the RAMS was directly used to support this use case, but the data can easily be integrated in the future if needed based on the LRS attributes present in the crash and work zone data.

Database Structure – Safety Use Case

The WZAD framework and dictionary do not currently define the outputs for the safety performance measures. Because of this, existing outputs and database structures were utilized. The following describes the database structure of the outputs for the safety performance measure.

To support the safety performance use case, two separate output tables are created. The first output, as shown in Table 6, provides a detailed list of the crashes associated to a work zone based on the unique identifier for each crash.

Table 6. Database structure for relating work zones and crashes

Field Name	Field Description
wz-SubTaskID	Work zone unique identifier in WZDB
direction	Direction of travel for work zone
CrashKey	The unique identifier for the crash data
Cseverity	Coded value for crash severity
WZrelated	Indicator variable submitted in crash report if the crash was work zone related

This table was created to support additional analysis in the future that may utilize additional crash data attributes not retained for the performance measure reporting. The only crash data attributes currently retained for the crash data are the severity and the coded value for whether or not the crash was work zone related.

The second database, with the fields shown in **Error! Not a valid bookmark self-reference.**, provides a summary for each work zone based on the number of crashes.

Table 7. Database structure for safety performance

Field Name	Field Description	Units
wz-SubTaskID	Work zone unique identifier in WZDB	
direction	Direction of travel for work zone	
NumCrashes	Total number of crashes within work zone extents	crash count
NumFatal	Total number of fatal crashes	crash count
NumMaj	Total number of major injury crashes	crash count
NumMin	Total number of minor injury crashes	crash count
NumPos	Total number of possible injury crashes	crash count
NumPD	Total number of property damage only crashes	crash count
NumWZ	Total number of work zone coded crashes	crash count

The intention of this table is to provide a high level summary of the number of crashes by severity and how many were coded as work zone related. The table includes the unique identifier for each work zone, which can be related back to the WZDB.

Data Processing – Safety Use Case

With the data inputs defined and processed as well as the output database defined, the process of calculating the work zone safety performance measures use case was developed. This section describes the implemented process for calculating the work zone safety performance measures.

An overview of the data inputs and processing of the data to support the safety performance process is shown in Figure 11.

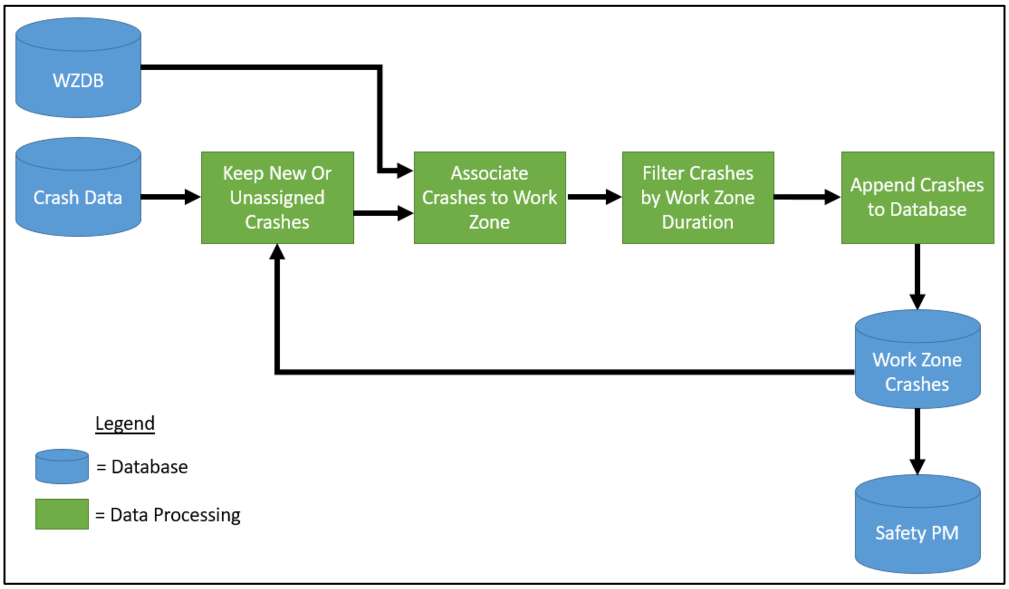


Figure 11. Safety performance measure process

The process is set up to run once per day and to update the work zone crash and safety performance measures for any work zone data that were archived in the WZDB. Safety performance varies significantly from mobility performance because the assumption that all data are complete at the end of each day is not valid. The work zone data should be complete given that data is updated every five minutes. The crash data is only updated once a week and contains only the crash data that has been submitted.

Data for most crashes are submitted within a few days or weeks, but in some situations it can be multiple months or more before the crash data are submitted and available within the database. Because of this, all of the crash data and work zone data must be considered in each update to ensure that new crash data, which may be from a few months ago, have the ability to be associated to the correct work zone that was active at the time of the crash. Given that all data must be considered, steps were taken to reduce the amount of data to be processed each day by removing any crashes that were already associated to a work zone.

The first step in the process in associating crash data to work zones is to utilize the work zone crash database that is an output of the overall process. This database is used to filter out any crash keys that are already associated to a work zone, so that only new or unassigned crashes are processed. Because the existing crash database does not track when the crash was added to the database, all unassigned crashes are considered new. A future enhancement of the data processing can be to compare the latest data with the previously delivered data so only crashes added to the database are processed, which should increase the speed and efficiency of the system.

The next step in the process is to assign each of the crashes to a corresponding work zone. No filtering is done on the WZDB as all historical work zone data must be considered given it is not known whether or not any new crashes in the database are from multiple months before the current data processing, for example.

The wZ-SubtaskID is used as the unique identifier for each work zone for the remainder of the data processing. The crashes are assigned to the work zones based on the LRS attributes for each dataset. At this point in the process, each crash is assigned to any work zone where the crash measure value is located between the begin and end measures of the work zone. A filter is then applied to keep only the crashes with a crash time that occurs within the start and end times reported in the WZDB. After the filter is applied, only crashes that are within the spatial extents of the work zone as well as the active time periods are retained.

Because only new or assigned crashes are processed each day, any output from the previous step should be appended to the work zone crash database. The data in this database will contain each crash key and the corresponding work zone unique identifier, wZ-SubtaskID, for linking the two databases together.

This supports two efforts for the use case. First, the database contains all crash keys that are associated to a work zone, which can be used for additional analysis beyond the safety performance measures developed in this process. Given the crash keys are available, additional data from the crash database can be used for more robust analysis of work zone crashes. The second effort for the database, which was previously described, is to be used as an input to eliminate the need to re-process crash data that have already been assigned to a work zone.

The final safety performance measure database output utilizes the work zone crash database. This final step aggregates all of the crash data based on the work zone subtask id and calculates the total number of crashes, total number of crashes by severity, and total number of work zone related coded crashes. The output allows for a high level summary of each work zone by direction that can then be aggregated to higher levels if necessary.

This database is overwritten each day as the crash data are likely to change for each work zone if older crashes are added to the database. This ensures that the performance measures represent all of the crashes that have been associated to the work zone to date.

Agency Project Initiation and Planning TTC Coordination

Unlike the previous two use cases, the agency project initiation and planning TTC coordination use case focuses on which planning data are available and whether or not a database can be established based on the traffic control plans. This database includes data elements such as the number of phases, the traffic control specification, restrictions, and other attributes.

This use-case is an early exploration of the design and planning process to determine how the data can be most effectively collected for future development. The next section describes how the TTC coordination use case could be implemented as part of the Iowa Work Zone Data Hub.

To begin, the following provides details of the use case as described in the WZAD framework:

WZAD Category: Work Zone Planning and Project Coordination

WZAD Description: Agency coordinates plans for multiple projects along a particular facility to ensure travel path continuity.

WZAD Example Use Cases: Agency has a list of capital improvement construction projects (new construction or reconstruction/widening), and/or a list of resurfacing, restoration, and rehabilitation (3R) projects to prioritize and coordinate (which ones to complete first, which ones should not happen at the same time because they affect the same motorists, etc.).

As suggested, the WZAD architecture was the starting place for the research team to identify the data elements needed for the work zone data hub. Table 8 includes all of the data elements identified in the WZAD dictionary and shows the availability of the data in Iowa.

Table 8. Data elements for TTC coordination use case

Use Category Data	Data Availability
Owner Agency	
Funding Allocation Status	
Project ID	
Event ID	
Name of the Roadway where event/subevent is located	
Roadway classification of roadway where event/subevent is located	
Facility type of roadway where event/subevent is located	
Direction of travel of event/subevent	
Planned begin location of event/subevent	
Planned end location of event/subevent	
Planned start date/time of event/subevent	
Planned Project Duration	

Use Category Data	Data Availability
Indicator for level of confidence in expected start date	
Status	
General description of event/subevent	

Integrating Data Sources – TTC Coordination Use Case

Iowa did not currently have a database to collect the data required for TTC coordination. Some or most of the data elements are collected and added to various databases as the information is needed but cannot easily be pulled from a single system.

For this use case, the research team used project plans to identify whether or not the data were available, and specifically within the project plan J sheets, and how these data could be translated into a database. It is expected that better methods may be available within the Iowa DOT to collect and input these data, but the project plans allowed the research team access to various types of project plan data.

The research team used the Iowa DOT Contracts website (https://iowadot.gov/contracts/plans-and-estimation-proposals) to download project plans for various lettings in 2020. A diverse set of projects were selected as the project plans can vary slightly and a goal for this use case was to be able to standardize the information into a single database.

Database Structure – TTC Coordination Use Case

The WZAD framework and dictionary defined both the types of data that should be collected as well as a summary of the various data elements. Using this information, Table 9 provides an overview of the fields identified to support the TTC coordination use case.

Table 9. Database structure for TTC coordination

Field Name	Field Description	Conformance
orgName	Name of the organization associated with a project	Required
orgType	Type of organization associated with a project	Optional
orgTelephone	Contact number for organization	Optional
region	Known jurisdiction or area	Optional
orgURL	Website for organization	Optional
allocationValue	Funding requirements for project	Optional
projectID	Unique identifier for the project	Required
projectLength	Length of the project	Optional
projectName	Name of the project	Required
phaseID	Unique identifier for project phase	Required

Field Name	Field Description	Conformance
BeginLocation/roadName	Name of the roadway the project begins on	Required
BeginLocation/roadDirection	Direction associated with roadway begin location	Required
BeginLocation/Milepost	Milepost of the begin location	Optional
BeginLocation/crossStreet	Cross street of the begin location	Optional
BeginLocation/ramp	The ramp associated with the locations	Conditional
EndLocation/roadName	Name of the roadway the project ends on	Required
EndLocation/roadDirection	Direction associated with roadway end location	Required
EndLocation/Milepost	Milepost of the end location	Optional
EndLocation/crossStreet	Cross street of the end location	Optional
EndLocation/ramp	The ramp associated with the end location	Conditional
facilityType	The type of road facility	Optional
startDateTime-est	Estimated start date time	Required
endDateTime-est	Estimated end date time	Required
wz-Status	Status of the work zone	Optional
descriptionTask	Description of the work zone task	Optional
projectDescription	Description of the project	Required
workClassificationDetail	List of work associated with a class of work	Optional
workClassificationType	Classification scheme associated with work zone	Optional
wzTTCType	Temporary traffic control standard	Optional

The data are anticipated to be collected on the planning side of the work zone lifecycle and could be used for future reference by other databases. In the table, the projectID would be the unique identifier, which may have multiple task, subtask, or phases within it.

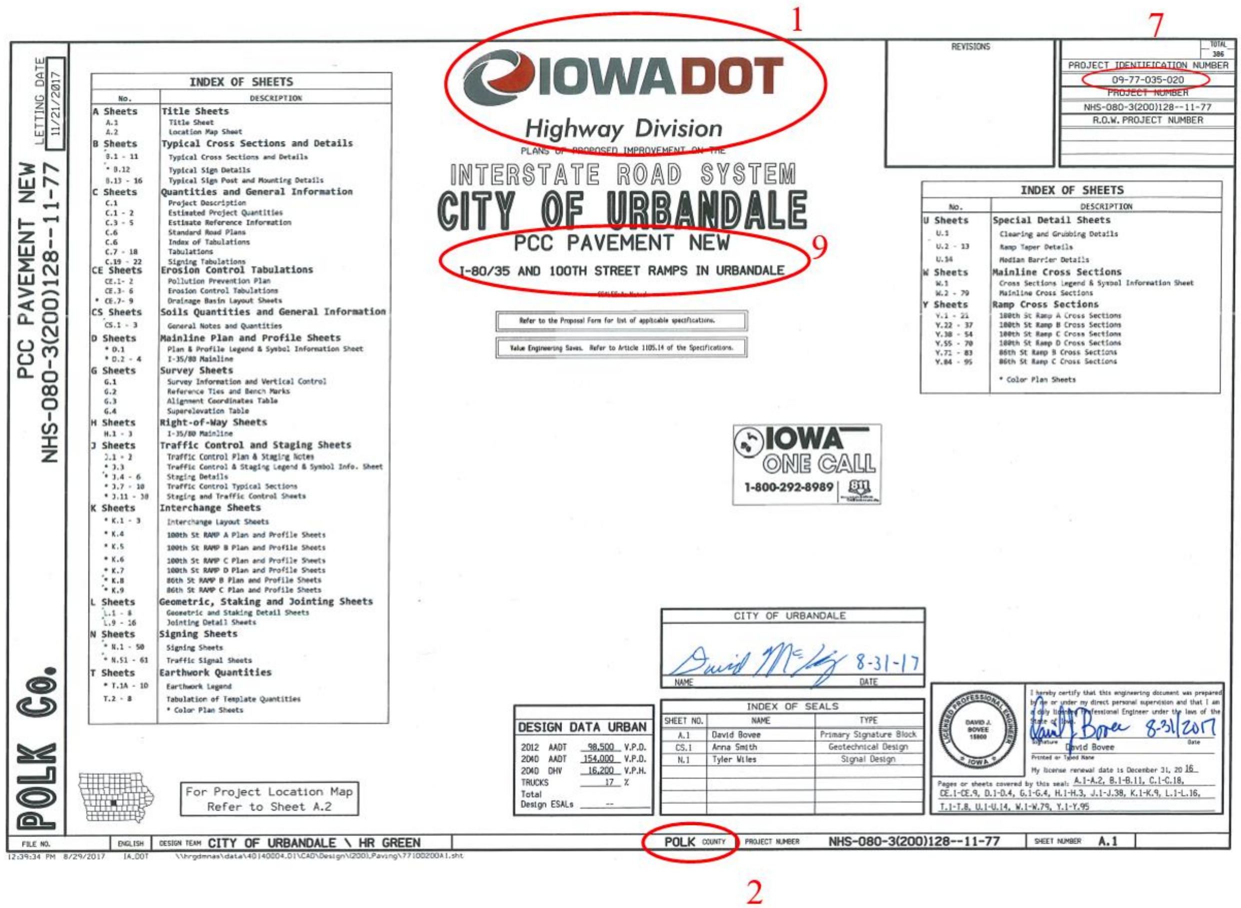
Data Processing – TTC Coordination Use Case

As previously mentioned, the goal for this use case is to identify potential areas that the data for the defined database can be collected. The remainder of this section focuses on the various data elements in Table 9 and how they can be extracted from the project plans.

For this effort, the research team downloaded multiple project plans from the Iowa DOT's website ensuring they downloaded various work zone types and complexities. Project plans have standard sections, but the location and specific information may vary slightly between plans. By using multiple project plans, the research team hoped to be able to account for any potential variations between the plans. To reiterate, it is not expected that the project plans will be the method of extracting the data in the future, as better systems and processes may be used to retrieve the data. The overall goal of this effort was to see how readily available the data are to highlight whether the data could be obtained for the variety of work zone projects that the research team considered.

In total, 10 different project plans were reviewed and entered into a database using the following methodology.

The following attributes contain high-level details about the project and can be extracted from the A sheets in a project plan, as shown in Figure 12.



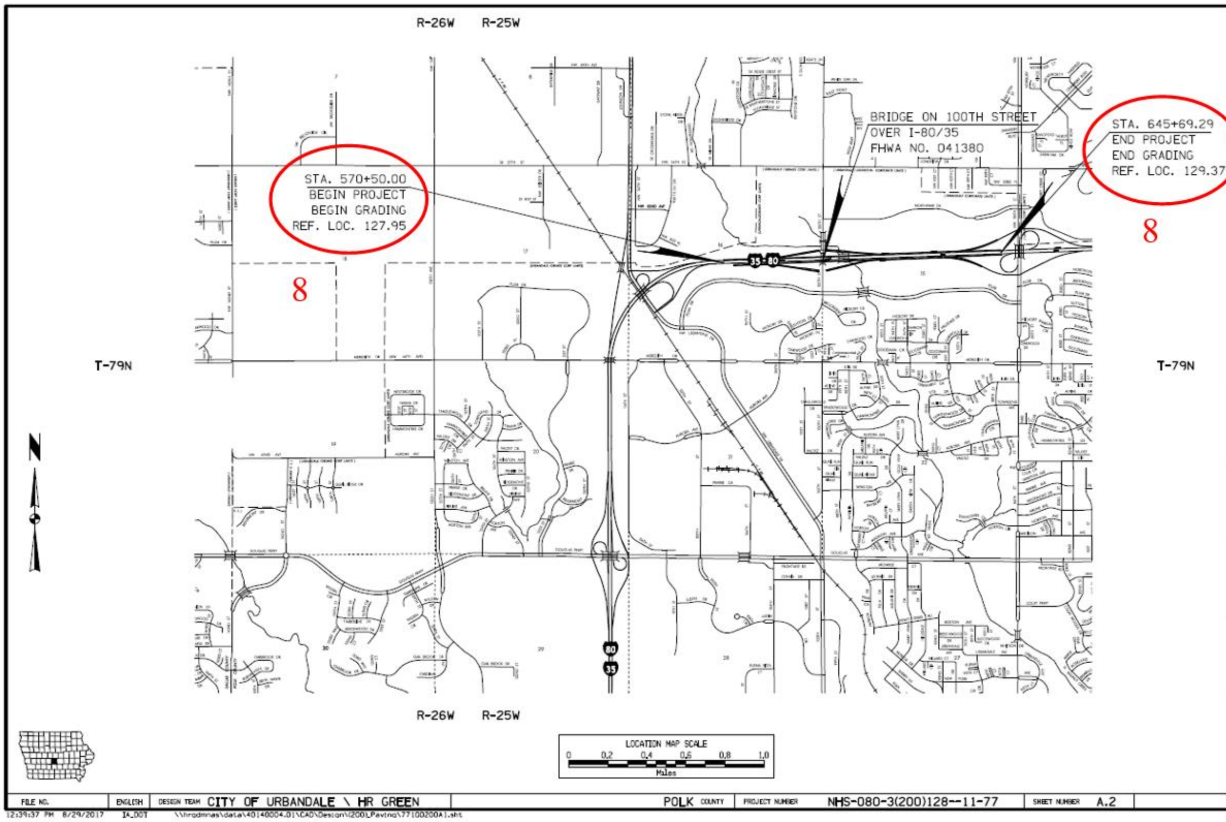


Figure 12. Data from A sheets

Any data elements are called out by number directly in the figure and correspond to the following numbered data elements:

1. orgName – Sheet A.1 typically contains the organization performing the work, but in most situations the Iowa DOT is the organization.

2. orgType – Information not available in the project plans but should be consistent for all Iowa DOT projects.

3. orgTelephone – Information not available in the project plans but the relevant resident construction engineer (RCE) contact information could be added once it is known.

4. region – The county could be considered the region as shown in sheet A.1, but a better method that directly relates to the Iowa DOT would be to use the Iowa DOT district numbers. This information is not currently available in the plans but could be added once it is known or easily identified based on the districts' responsibilities.

5. orgURL – Information not available, but similar to the orgName, will almost always be the Iowa DOT website.

6. allocationValue – The allocation value is not provided in the project plans but could be added through other systems within the Iowa DOT.

7. projectID – For all project plans, the project identification number was always provided in the top right corner of sheet A.1.

8. projectLength – The length of the project varied between the project plans. For a majority of the plans, the information was available as either an inset on sheet A.1 or sheet A.2. Both of these locations provided a start and end location with either a milepost or station number, which could then be used to calculate the project length. In some plans, the project length is reported directly on sheet A.1, while one plan only showed the location of the work. The one plan that showed the location was a bridge replacement and additional work was necessary to identify on other sheets where the project extents were located.

9. projectName – Each project is not given a specific name but various attributes on sheet A.1 could be used for consistency. Typically, in the center of the page number, the county name is a general description of the work activity as well as the written description of the location. The research team proposed using both of these values for the project name

10. workClassificationDetail – The WZAD doesn't provide enumeration or definition for the classification details for the work. The Iowa DOT does use some standard descriptions for work zone activity, which are typically located under the city or county name on sheet A.1. This value could be input into this section, or a set of enumerated values could be developed.

11. workClassificationType – The WZAD provides the following enumerations for this data element: In-House-Maintenance-Operations, Contract-Maintenance, Construction, Utility, Vertical-Construction, and Special-Event-Traffic-Control. Because all of the project plans that were reviewed were for construction, no details were extracted from the plans. This may differ for other work classification types.

For the next set of attributes, the J sheets, which contain the traffic control details, are used. This information is not currently collected in any known databases and could be a potential opportunity for easier input into a lane-closure system that the Iowa DOT is developing. The details on phases and traffic control could make tremendous improvements on the quality of the data and other performance analysis.

The phase or stage of the project is located within the J sheets. Under each phase or stage, the sheet lists the planned construction activities, which also may have subparts that need to be identified, as follows:

1. phaseID – The phase numbers for a project are typically located in the Staging Notes or in the Traffic Control Plan that are located on sheet J.1 and/or sheet J.2, as shown in Figure 13.

108-23A
08-01-08

TRAFFIC CONTROL PLAN

Mainline I-35/80

1. Maintain three lanes of traffic, both northbound/eastbound and southbound/westbound, at all times during all stages of construction, except when night-time single lane closures are allowed by the Engineer. No Interstate access to the project during daytime hours.
2. If single lane closures on I-35/80 are needed for delivery of equipment or materials, night-time restrictions shall be required. Closures will be short-term in duration and restricted to off-peak travel hours (Sunday through Friday, 8:00 PM - 5:00 AM). Lane closures will not be allowed Friday or Saturday evenings. Notify the Engineer at least 72 hours in advance of the proposed lane closure. The Engineer has final approval of proposed time and duration of lane closure.
3. Limited closured will be necessary on Interstate 35/80 to install the sign truss supports and overhead signs. Use "Modified" Standard Road Plan TC-454 within the J Sheets to detour traffic utilizing the new 100th Street ramps and the 86th Street ramps for the sign trusses at Sta. 586+41, Sta. 598+76, and Sta. 660+50. Use Standard Road Plan TC-451 for the sign truss support and overhead signs at Sta. 629+80. The Contractor shall be responsible for installing, maintaining, and removing the detour signage; including uncovering and re-covering the detour signs as necessary. Closures will be short-term and restricted to off-peak travel hours (12:00 AM to 5:00 AM). Notify the Engineerat least 72 hours in advance of the proposed closure. The Engineer has final approval of proposed time and duration of closure.
4. Coordinate traffic signal timing along the proposed detour routes with the City of Urbandale.
5. Shoulder closures will be required to install the median sign truss support footings. Refer to Shoulder Closure Details within the J Sheets for information.
6. Delivery of equipment and materials to the median area shall be done during off-peak travel hours (Sunday through Friday, 8:00 PM - 5:00 AM).

100th Street

1. Maintain traffic on northbound and southbound 100th Street at all times during all stages of construction.
2. Provide safety closures at each ramp terminal at 100th Street.
3. Lane closures along 100th Street shall be coordinated with the City of Urbandale. Notify the Engineer at least 72 hours in advance of the proposed land closures.

100th Street Interchange

1. Ramp A will be closed until the project completed in its entirety.
2. Ramps B, C, and D will open between Stage 1 and Stage 2.

86th Street Interchange

1. The SB on-ramp (Ramp C) and NB off-ramp (Ramp B) will be closed during Stages 2 and 3. Traffic to follow marked detour in the J sheets.
2. Both ramps will be closed until the project is completed in its entirety.

111-01
04-17-12

COORDINATED OPERATIONS

Other work in progress during the same period of time will include the construction of the projects listed. Coordinate operations with those of other contractors working within the same area.

Project	Type of Work
STP-U-7875(650)--70-77	86th Street HMA Resurfacing

108-26A
08-01-08

STAGING NOTES

TRAFFIC CONTROL (Refer to sheets J.3 to J.38)

STAGE 1A (Sign Truss Footings)

Traffic:
1. NB and SB I-35/80 traffic will operate on existing mainline pavement. Maintain three lanes at all times.
2. Close median shoulder using temporary barrier rail placed a minimum of 2.5' from the edge of the existing inside lane line.

Construction:
1. Construct median overhead sign truss footings at Sta. 586+41, Sta. 598+76, Sta. 629+80, and Sta. 660+50 using shoulder closure and temporary barrier rail.

STAGE 1B

Traffic:
1. Shift traffic per Stage 1 Traffic Control Layout.
2. Ramps at 100th Street terminals to remain closed.

Construction:
1. Remove existing SB shoulder pavement from Sta. 570+50.00 to Sta. 621+23.00 and NB shoulder pavement from Sta. 573+20.00 to Sta. 622+50.00.
2. Grade I-35/80:
   SB lane 4, auxiliary lane, and shoulder from Sta. 570+50.00 to Sta. 621+23.00.
   NB lane 4, auxiliary lane, and shoulder from Sta. 573+20.00 to Sta. 622+50.00.
3. Pave I-35/80:
   SB lane 4, auxiliary lane, and shoulder from Sta. 570+50.00 to Sta. 621+23.00.
   NB lane 4, auxiliary lane, and shoulder from Sta. 573+20.00 to Sta. 622+50.00.
4. Pave 100th Street Ramps B, C, and D.
5. Construct overhead sign and cantilever truss footings between Sta. 570+50.00 and Sta.622+50.00.
6. Install 100th Street Traffic Signals.
7. Install permanent 100th Street signing and pavement markings.
8. Install permanent I-35/80 signing, not in conflict, as directed by the Iowa DOT field personnel.
9. Install temporary erosion control items.

STAGE 2

Traffic
1. Shift traffic per Stage 2 Traffic Control Layout.
2. Open 100th Street Ramps B, C, and D.
3. Install detour signing and close 86th Street SB on ramp and NB exit ramp.
4. 100th Street Ramp A to remain closed.

Construction
1. Remove existing SB shoulder pavement from Sta. 621+23.00 to Sta. 645+50.38 and NB shoulder pavement from Sta. 622+50.00 to Sta. 645+69.29.
2. Remove 86th Street Ramp Pavement.
3. Construct all proposed pipes and culvert extensions.
4. Grade SB I-35/80 from Sta. 621+23.00 to Sta. 645+50.38.
5. Grade NB I-35/80 from Sta. 622+50.00 to Sta. 645+69.29.
6. Install temporary erosion control items.

STAGE 3

Traffic
1. Maintain traffic per Stage 2/3 Traffic Control Layout.
2. 86th Street SB on ramp and NB exit ramp to remain closed.
3. 100th Street Ramp A to remain closed.

Construction
1. Pave SB I-35/80 from Sta. 621+23.00 to Sta. 645+50.38.
2. Pave NB I-35/80 from Sta. 622+50.00 to Sta. 645+69.29.
3. Pave 86th Street Ramps.
4. Pave 100th Street Ramp A.
5. Install remaining permanent I-35/80 signing and pavement markings.
6. Install temporary erosion control items.

STAGE 4

Traffic
1. Shift Traffic to Stage 4 (Permanent) Traffic Control Layout.
2. Remove Detour signing.
3. Open 86th Street ramps.
4. Open 100th Street Ramp A.

Construction
1. Install permanent erosion control items.

FILE NO.	ENGLISH	DESIGN TEAM CITY OF URBANDALE \ HR GREEN	POLK COUNTY	PROJECT NUMBER NHS-080-3(200)128--11-77	SHEET NUMBER J.1

8/29/2017 12:06:43 PM dbovee \\HRGDMNAS\Data\40140004.01\CAD\Design\(200)_Paving\Excel\7710020031.xlsm

Figure 13. Example sheet J.1

The phaseID data can be obtained by reading through the notes and pulling out each stage and the substages and creating a record for each in the database. It is recommended that the phaseID field type allows for text characters, given that number and letter combinations for stages are common across projects.

2. BeginLocation/roadName – For the begin location, each of the project plans that were reviewed provided detailed maps showing the relevant closures for each stage. Information such as road name and direction could be extracted from these maps, but other details such as the milepost were not easily available. The approximate locations could be obtained, but more detailed data may be available from the computer-aided design (CAD) files for each direction. In addition, the milepost used to derive the project length could be utilized from sheet A.1 or A.2, but those data represent the overall project limits, which may vary between stages.

3. BeginLocation/roadDirection – See BeginLocation/roadName.

4. BeginLocation/Milepost See – See BeginLocation/roadName.

5. BeginLocation/crossStreet – See BeginLocation/roadName.

6. BeginLocation/ramp – See BeginLocation/roadName.

7. EndLocation/roadName – Similar scenarios exist for the end location as the BeginLocation/roadName.

8. EndLocation/roadDirection – See EndLocation/roadName.

9. EndLocation/Milepost – See EndLocation/roadName.

10. EndLocation/crossStreet – See EndLocation/roadName.

11. EndLocation/ramp – See EndLocation/roadName.

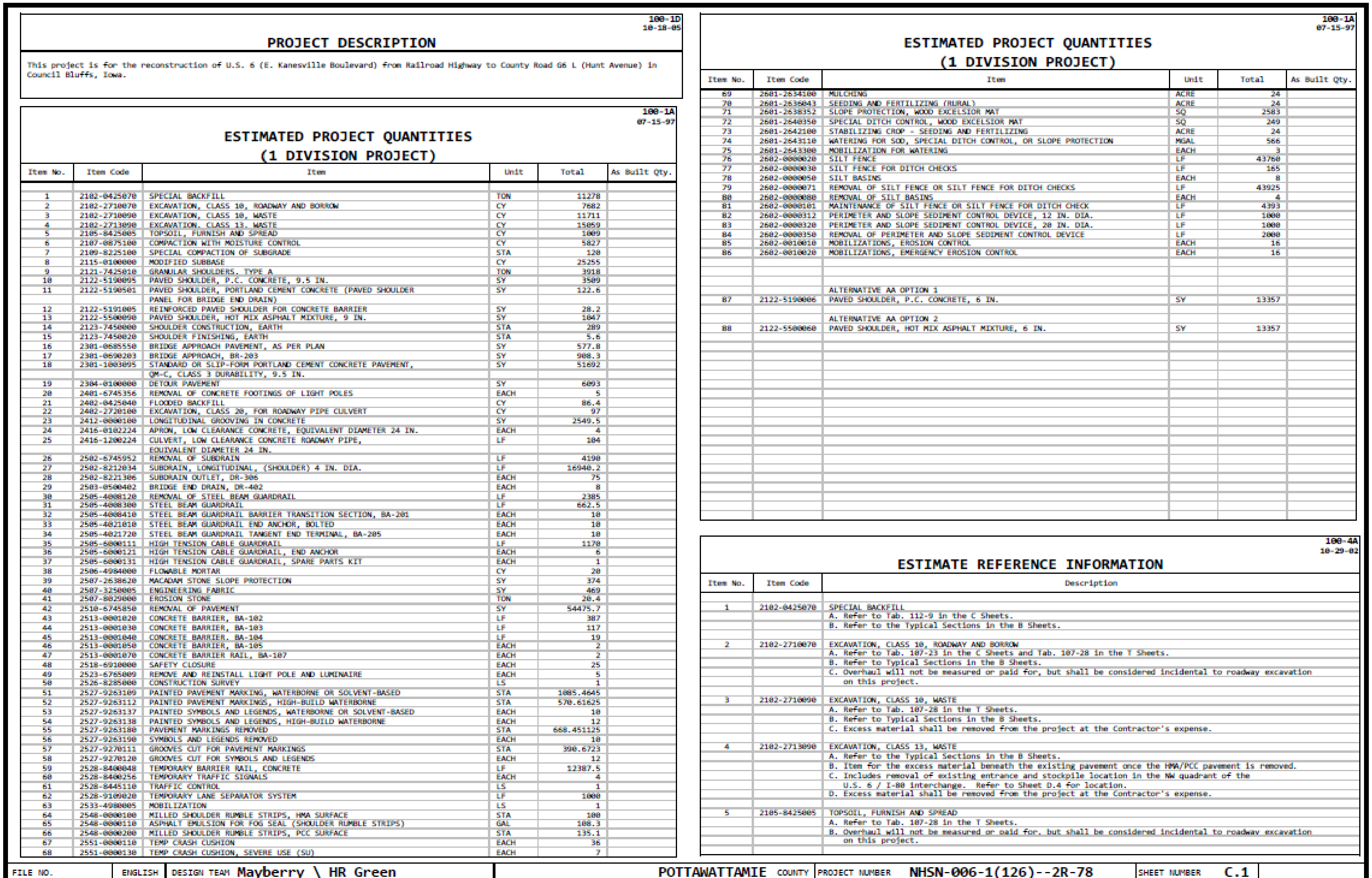
12. facilityType – The facility type has the enumeration values of mainline, connector, ramp, and shoulder. Generally, from the traffic control plan and staging notes, the impacted area can be identified and input into this field.

13. descriptionTask – It is recommended that the task description use the description from the staging notes section of the J sheets as input into the description task.

14. wzTTCType – The goal of the research team was to be able to assign standard traffic control plans (https://iowadot.gov/erl/current/RS/Navigation/tc.htm) as documented by the Iowa DOT for each phase of a project. Only two of the 10 plans had notes explicitly describing

which standard should be used in each phase. One additional plan contained the traffic control standard in the maps, which could be assigned to a stage but not directly noted. For the remaining plans, it was not possible to identify the traffic control standard. To note, the relevant traffic control standards are listed in the C sheets under the standard road plans. It is possible that a designer may be able to identify the traffic control standard from the traffic control maps, but a better method of obtaining the traffic control standard should be developed during the planning and design phases of a work zone within the Iowa DOT.

15. projectDescription – The project description was standardized across all of the project plans and was located on sheet C.1. The information from this sheet, as shown in **Error! Reference source not found.**, can be used for all stages.



100-1D
10-18-05

PROJECT DESCRIPTION

This project is for the reconstruction of U.S. 6 (E. Kanesville Boulevard) from Railroad Highway to County Road G6 L (Hunt Avenue) in Council Bluffs, Iowa.

100-1A
07-15-97

ESTIMATED PROJECT QUANTITIES (1 DIVISION PROJECT)

Item No.	Item Code	Item	Unit	Total	As Built Qty.
1	2102-0425070	SPECIAL BACKFILL	TON	11278	
2	2102-2710070	EXCAVATION, CLASS 10, ROADWAY AND BORROW	CY	7682	
3	2102-2710090	EXCAVATION, CLASS 10, WASTE	CY	11711	
4	2102-2713090	EXCAVATION. CLASS 13. WASTE	CY	15059	
5	2105-8425005	TOPSOIL, FURNISH AND SPREAD	CY	1009	
6	2107-0875100	COMPACTION WITH MOISTURE CONTROL	CY	5827	
7	2109-8225100	SPECIAL COMPACTION OF SUBGRADE	STA	120	
8	2115-0100000	MODIFIED SUBBASE	CY	25255	
9	2121-7425010	GRANULAR SHOULDERS. TYPE A	TON	3918	
10	2122-5190095	PAVED SHOULDER, P.C. CONCRETE, 9.5 IN.	SY	3509	
11	2122-5190501	PAVED SHOULDER, PORTLAND CEMENT CONCRETE (PAVED SHOULDER	SY	122.6	
		PANEL FOR BRIDGE END DRAIN)			
12	2122-5191005	REINFORCED PAVED SHOULDER FOR CONCRETE BARRIER	SY	28.2	
13	2122-5500090	PAVED SHOULDER, HOT MIX ASPHALT MIXTURE, 9 IN.	SY	1047	
14	2123-7450000	SHOULDER CONSTRUCTION, EARTH	STA	289	
15	2123-7450020	SHOULDER FINISHING, EARTH	STA	5.6	
16	2301-0685550	BRIDGE APPROACH PAVEMENT, AS PER PLAN	SY	577.8	
17	2301-0690203	BRIDGE APPROACH, BR-203	SY	908.3	
18	2301-1003095	STANDARD OR SLIP-FORM PORTLAND CEMENT CONCRETE PAVEMENT,	SY	51692	
		QM-C, CLASS 3 DURABILITY, 9.5 IN.			
19	2304-0100000	DETOUR PAVEMENT	SY	6093	
20	2401-6745356	REMOVAL OF CONCRETE FOOTINGS OF LIGHT POLES	EACH	5	
21	2402-0425040	FLOODED BACKFILL	CY	86.4	
22	2402-2720100	EXCAVATION, CLASS 20, FOR ROADWAY PIPE CULVERT	CY	97	
23	2412-0000100	LONGITUDINAL GROOVING IN CONCRETE	SY	2549.5	
24	2416-0102224	APRON, LOW CLEARANCE CONCRETE, EQUIVALENT DIAMETER 24 IN.	EACH	4	
25	2416-1200224	CULVERT, LOW CLEARANCE CONCRETE ROADWAY PIPE,	LF	104	
		EQUIVALENT DIAMETER 24 IN.			
26	2502-6745952	REMOVAL OF SUBDRAIN	LF	4190	
27	2502-8212034	SUBDRAIN, LONGITUDINAL, (SHOULDER) 4 IN. DIA.	LF	16940.2	
28	2502-8221306	SUBDRAIN OUTLET, DR-306	EACH	75	
29	2503-0500402	BRIDGE END DRAIN, DR-402	EACH	8	
30	2505-4008120	REMOVAL OF STEEL BEAM GUARDRAIL	LF	2385	
31	2505-4008300	STEEL BEAM GUARDRAIL	LF	662.5	
32	2505-4008410	STEEL BEAM GUARDRAIL BARRIER TRANSITION SECTION, BA-201	EACH	10	
33	2505-4021010	STEEL BEAM GUARDRAIL END ANCHOR, BOLTED	EACH	10	
34	2505-4021720	STEEL BEAM GUARDRAIL TANGENT END TERMINAL, BA-205	EACH	10	
35	2505-6000111	HIGH TENSION CABLE GUARDRAIL	LF	1170	
36	2505-6000121	HIGH TENSION CABLE GUARDRAIL, END ANCHOR	EACH	6	
37	2505-6000131	HIGH TENSION CABLE GUARDRAIL, SPARE PARTS KIT	EACH	1	
38	2506-4984000	FLOWABLE MORTAR	CY	20	
39	2507-2638620	MACADAM STONE SLOPE PROTECTION	SY	374	
40	2507-3250005	ENGINEERING FABRIC	SY	469	
41	2507-8029000	EROSION STONE	TON	20.4	
42	2510-6745850	REMOVAL OF PAVEMENT	SY	54475.7	
43	2513-0001020	CONCRETE BARRIER, BA-102	LF	387	
44	2513-0001030	CONCRETE BARRIER, BA-103	LF	117	
45	2513-0001040	CONCRETE BARRIER. BA-104	LF	19	
46	2513-0001050	CONCRETE BARRIER, BA-105	EACH	2	
47	2513-0001070	CONCRETE BARRIER RAIL, BA-107	EACH	2	
48	2518-6910000	SAFETY CLOSURE	EACH	25	
49	2523-6765009	REMOVE AND REINSTALL LIGHT POLE AND LUMINAIRE	EACH	5	
50	2526-8285000	CONSTRUCTION SURVEY	LS	1	
51	2527-9263109	PAINTED PAVEMENT MARKING, WATERBORNE OR SOLVENT-BASED	STA	1085.4645	
52	2527-9263112	PAINTED PAVEMENT MARKINGS, HIGH-BUILD WATERBORNE	STA	570.61625	
53	2527-9263137	PAINTED SYMBOLS AND LEGENDS, WATERBORNE OR SOLVENT-BASED	EACH	10	
54	2527-9263138	PAINTED SYMBOLS AND LEGENDS, HIGH-BUILD WATERBORNE	EACH	12	
55	2527-9263180	PAVEMENT MARKINGS REMOVED	STA	668.451125	
56	2527-9263190	SYMBOLS AND LEGENDS REMOVED	EACH	10	
57	2527-9270111	GROOVES CUT FOR PAVEMENT MARKINGS	STA	390.6723	
58	2527-9270120	GROOVES CUT FOR SYMBOLS AND LEGENDS	EACH	12	
59	2528-8400048	TEMPORARY BARRIER RAIL, CONCRETE	LF	12387.5	
60	2528-8400256	TEMPORARY TRAFFIC SIGNALS	EACH	4	
61	2528-8445110	TRAFFIC CONTROL	LS	1	
62	2528-9109020	TEMPORARY LANE SEPARATOR SYSTEM	LF	1000	
63	2533-4980005	MOBILIZATION	LS	1	
64	2548-0000100	MILLED SHOULDER RUMBLE STRIPS, HMA SURFACE	STA	100	
65	2548-0000110	ASPHALT EMULSION FOR FOG SEAL (SHOULDER RUMBLE STRIPS)	GAL	108.3	
66	2548-0000200	MILLED SHOULDER RUMBLE STRIPS, PCC SURFACE	STA	135.1	
67	2551-0000110	TEMP CRASH CUSHION	EACH	36	
68	2551-0000130	TEMP CRASH CUSHION, SEVERE USE (SU)	EACH	7	

100-1A
07-15-97

ESTIMATED PROJECT QUANTITIES (1 DIVISION PROJECT)

Item No.	Item Code	Item	Unit	Total	As Built Qty.
69	2601-2634100	MULCHING	ACRE	24	
70	2601-2636043	SEEDING AND FERTILIZING (RURAL)	ACRE	24	
71	2601-2638352	SLOPE PROTECTION, WOOD EXCELSIOR MAT	SQ	2583	
72	2601-2640350	SPECIAL DITCH CONTROL, WOOD EXCELSIOR MAT	SQ	249	
73	2601-2642100	STABILIZING CROP - SEEDING AND FERTILIZING	ACRE	24	
74	2601-2643110	WATERING FOR SOD, SPECIAL DITCH CONTROL, OR SLOPE PROTECTION	MGAL	566	
75	2601-2643300	MOBILIZATION FOR WATERING	EACH	3	
76	2602-0000020	SILT FENCE	LF	43760	
77	2602-0000030	SILT FENCE FOR DITCH CHECKS	LF	165	
78	2602-0000050	SILT BASINS	EACH	8	
79	2602-0000071	REMOVAL OF SILT FENCE OR SILT FENCE FOR DITCH CHECKS	LF	43925	
80	2602-0000080	REMOVAL OF SILT BASINS	EACH	4	
81	2602-0000101	MAINTENANCE OF SILT FENCE OR SILT FENCE FOR DITCH CHECK	LF	4393	
82	2602-0000312	PERIMETER AND SLOPE SEDIMENT CONTROL DEVICE, 12 IN. DIA.	LF	1000	
83	2602-0000320	PERIMETER AND SLOPE SEDIMENT CONTROL DEVICE, 20 IN. DIA.	LF	1000	
84	2602-0000350	REMOVAL OF PERIMETER AND SLOPE SEDIMENT CONTROL DEVICE	LF	2000	
85	2602-0010010	MOBILIZATIONS, EROSION CONTROL	EACH	16	
86	2602-0010020	MOBILIZATIONS, EMERGENCY EROSION CONTROL	EACH	16	
		ALTERNATIVE AA OPTION 1			
87	2122-5190006	PAVED SHOULDER, P.C. CONCRETE, 6 IN.	SY	13357	
		ALTERNATIVE AA OPTION 2			
88	2122-5500060	PAVED SHOULDER, HOT MIX ASPHALT MIXTURE, 6 IN.	SY	13357	

100-4A
10-29-02

ESTIMATE REFERENCE INFORMATION

Item No.	Item Code	Description
1	2102-0425070	SPECIAL BACKFILL
		A. Refer to Tab. 112-9 in the C Sheets.
		B. Refer to the Typical Sections in the B Sheets.
2	2102-2710070	EXCAVATION, CLASS 10, ROADWAY AND BORROW
		A. Refer to Tab. 107-23 in the C Sheets and Tab. 107-28 in the T Sheets.
		B. Refer to Typical Sections in the B Sheets.
		C. Overhaul will not be measured or paid for, but shall be considered incidental to roadway excavation on this project.
3	2102-2710090	EXCAVATION, CLASS 10, WASTE
		A. Refer to Tab. 107-28 in the T Sheets.
		B. Refer to Typical Sections in the B Sheets.
		C. Excess material shall be removed from the project at the Contractor's expense.
4	2102-2713090	EXCAVATION, CLASS 13, WASTE
		A. Refer to the Typical Sections in the B Sheets.
		B. Item for the excess material beneath the existing pavement once the HMA/PCC pavement is removed.
		C. Includes removal of existing entrance and stockpile location in the NW quadrant of the U.S. 6 / I-80 interchange. Refer to Sheet D.4 for location.
		D. Excess material shall be removed from the project at the Contractor's expense.
5	2105-8425005	TOPSOIL, FURNISH AND SPREAD
		A. Refer to Tab. 107-28 in the T Sheets.
		B. Overhaul will not be measured or paid for. but shall be considered incidental to roadway excavation on this project.

FILE NO. | ENGLISH | DESIGN TEAM Mayberry \ HR Green | POTTAWATTAMIE COUNTY | PROJECT NUMBER NHSN-006-1(126)--2R-78 | SHEET NUMBER C.1

Figure 14. Example Sheet C.1

SUMMARY

The ability to easily access work zone data in a standardized format is a desire for the Iowa DOT as well as many agencies across the nation. Work zones are unique in that they typically impact and involve all areas within a DOT. These areas cover the entire lifecycle of a work zone, which can have varying functions and data needs. Unfortunately, a common repository of these data is not available and agencies either do not collect the necessary data that may be beneficial for other parts of the agency or don’t have the ability to share that data.

The FHWA-led WZAD efforts attempt to provide a standardized schema and structure for collecting work zone data throughout the entire work zone lifecycle. The most significant benefit of the FHWA effort is expected to include a nationally consistent dictionary and framework for communicating and storing WZAD that also provides references to external databases containing related work zone data, e.g., mobility and crash data.

The research team began the development of the Iowa Work Zone Data Hub, which has a goal of being the repository for various work zone data in Iowa. The work zone data hub is not intended to be a platform to process and analyze work zone data but a location where the data can be easily obtained or related for use in other systems.

The number of stakeholders and use cases impacted by work zone data can be daunting for an agency in the beginning. The WZAD framework identified 50 different use cases, which involved 27 different stakeholders. The approach of the research team was to identify a select number of use cases that could be implemented or further explored. By focusing on a small number of use cases, the amount of data needed and the relevant stakeholders were reduced, making the initial implementation of the data hub more manageable. The project team expects that a cyclical effort can be done based on priority use cases for the Iowa DOT to continue to grow and expand the Iowa Work Zone Data Hub.

To select the initial use cases, the research team developed an Excel file that allowed for easier comparison of the various use cases documented in the WZAD framework and the corresponding data needs from the WZAD dictionary. Due to the comprehensiveness of the WZAD framework and dictionary, it can be challenging to work with the information to compare and prioritize among the use cases. The Excel file was utilized to simplify the process and provided the ability for the research team and the Iowa DOT to summarize and compare across the use cases. The Excel file included all of the key elements from the WZAD for each use case but also infused Iowa-specific priorities and data availability to give a more comprehensive picture of the use cases. For example, a use case in the Excel file could be filtered to show only the relevant data elements, and the data availability in Iowa can provide insights into the potential level of effort to implement the use case.

With the assistance of the Excel file, the 50 use cases were reduced down to 12. For those 12 use cases, a detailed summary was provided and presented to the Iowa DOT for prioritization. A survey was sent to the Iowa DOT in which each use case could be ranked by individual staff members. The results were summarized and the top five use cases were selected for initial implementation or exploration if the data were not currently available.

During the implementation phase of the project, one of the use cases was identified as being implemented by another bureau within the Iowa DOT, and the priorities for another use case changed for the Iowa DOT. Given these changes only three of the use cases were then selected for implementation or further exploration:

- Work Zone Mobility Performance Analysis
- Agency Project Initiation and Planning TTC Coordination
- Work Zone Safety Performance Analysis

The work zone mobility performance use case is a high priority for the Iowa DOT as this has been a primary output of the Iowa DOT's Traffic Critical Project (TCP) program. The implementation of this use case utilized the WZDB developed from a parallel project by the research team that archived work zone data from 511 and smart arrow boards using the WZAD dictionary. This database allowed for the expansion of the mobility performance measures to all work zones statewide.

The mobility performance measure use case used two methods for analysis—using probe and sensor data. The first step in the implementation of the use case for both datasets was to integrate all of the relevant data sources. The LRS was used as the common network to associate work zones, speed limits, traffic sensors, and probe data segments. Most datasets were already integrated with the LRS. For datasets that were not integrated, a process was established to relate the data to the LRS.

The WZAD framework does not currently define the mobility performance measure output. Because of this, the existing mobility measures that are used for the TCP program in Iowa were used with a modification to include the unique identifier from the WZDB. The steps for integrating and analyzing the data were developed, which resulted in a database for sensor-based and probe-based mobility performance measures. The outputs are created daily for tracking of mobility performance over time.

Improving work zone safety is another high priority for the Iowa DOT with multiple efforts being implemented to identify and associate crashes to work zones. Similar to the mobility use case, safety performance measures are currently used in Iowa for TCP projects, which represent only a small portion of the overall number of work zones.

By using the WZDB, the safety performance measures can be expanded statewide. All of the data inputs for the safety use case were identified and the LRS was again used as the common network for integrating the data. All datasets include documented processes for obtaining the LRS measures. The WZAD framework does not define the safety performance measure output, so the research team developed a database based on current efforts, which were again modified to include the unique identifier from the WZDB.

The steps for integrating and analyzing the data were developed with two databases created as the final outputs of the use case. One provides the direct mapping between the crash data and the WZDB while the other output summarizes the number of crashes and severity for each work zone. Unlike the mobility performance measures, the safety process is set up to run daily but will consider all historical data given the expected latency for when crash data are submitted.

After completion of the first two use cases, the overall relationship and structure of the WZDB is shown in Figure 15.

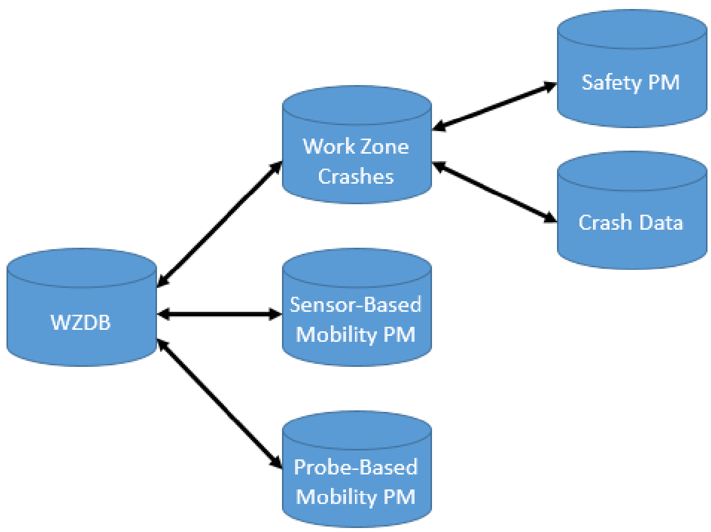


Figure 15. Relationship of databases from the mobility and safety performance use cases

A defined database for each of the use cases, along with the WZDB, are available with each database containing multiple tables within it. All databases, with the exception of the crash database, can be related based on the wZ-SubtaskID. This relationship allows for easy extraction of relevant data for future analysis if necessary. For example, if a given work zone is showing concerning trends for the sensor-based mobility performance measures, all of the details about that work zone can be easily extracted utilizing the wZ-SubtaskID.

The final use case focused on project initiation and planning TTC coordination. This use case differed from the previous two given no existing data sources were available making it an exploratory effort by the researchers to identify methods to collect the relevant data. The WZAD dictionary was used to identify the relevant data elements that would be necessary to support this use case.

The research team attempted to identify the data attributes by using project plans. The goal was to be able to show how the data for the use case could be extracted from the project plans and used to build a database. Most of the project-level attributes could be easily extracted using the A sheets in the project plans that were reviewed with most of the data being standard across all of the sheets. For project phasing, those details were also available in the project plans in the J sheets. These attributes were fairly standard with most data being located in two sections. However, the begin and end locations for each of the work zone phases were unfortunately not easily extracted and may be better to access directly from the design files.

The final attribute, which was of most interest, was the standard traffic control. Only three of the 10 plans reviewed linked a standard traffic control to a specific phase, even though the C sheets noted multiple standard traffic controls used in the project. This is an attribute that would have considerable benefits for real-time and historical analysis. The information would allow for more detailed comparisons across work zones with the understanding of the type of traffic control used. The team recommends that the Iowa DOT continue to explore methods of collecting these data and putting it into a database for future analysis.

REFERENCES

Knickerbocker, S., V. Ravichandra-Mouli, N. Hawkins, and A. Sharma. 2020. *Developing a Research-Grade Iowa Work Zone Database.* Center for Transportation Research and Education, Iowa State University, Ames, IA. https://intrans.iastate.edu/app/uploads/2020/12/research-grade_wz_db_dev_w_cvr.pdf.

Knickerbocker, S., S. Bhagat, Z. Hans, and A. Sharma. 2021. *Developing an Architecture to Integrate Safety, Mobility, and Traffic Data.* Center for Transportation Research and Education, Iowa State University, Ames, IA. https://intrans.iastate.edu/app/uploads/2021/06/safety_mobility_and_traffic_data_integration_arch_dev_w_cvr.pdf.

Okunieff, P., D. Stephens, and R. Ostroff. 2019. *Work Zone Activity Data (WZAD) – Data Dictionary Report (Version 2).* Federal Highway Administration, Washington, DC.

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APPENDIX

This appendix describes the performance measures used in the sensor-based mobility performance measures.

Non-Event-Based Performance Measures

1. *Total traffic* (vehicles): The maximum volume is selected among all the sensors within each minute. The volume is summed for each time period.

2. *Total vehicle hours of delay* (veh-hours): The delay is calculated by multiplying the number of vehicles by the travel time deficit. The travel time deficit is calculated by comparing the travel time calculated from monitored traffic speed against the travel time calculated from a reference speed (speed limit).

3. *Average vehicle hours of delay per vehicle* (veh-hours): This can be calculated by dividing the total delay by the total traffic.

4. *Maximum delay* (minutes): The maximum delay is found by summing the travel time deficit for all sensors (actual speed vs. speed limit) for each minute of data and then finding the maximum.

5. *95th percentile of delay for all times* (minutes): This is found by summing the travel time deficit for all sensors (actual speed vs. speed limit) for each minute of data and then finding the 95th percentile.

6. *Maximum vehicle hours of delay per minute* (veh-hours): The delay is calculated by multiplying the number of vehicles by the travel time deficit for each minute of data. From this, the minute that had the maximum vehicle hours of delay is found.

Event-Based Performance Measures

1. *Number of events:* Number of events that occurred in each time period. Events are identified based on a machine learning algorithm that was developed to identify slow and stopped conditions based on speed and occupancy. The supervised decision tree algorithm is based on Figure 16, where four different sections are identified.

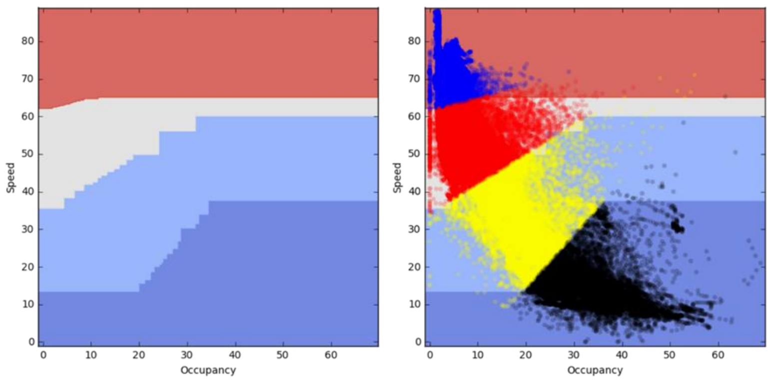

Figure 16. Decision tree for sensor slowdown classification

The decision regions are displayed from top to bottom for normal conditions with no message display, Traffic Delay Possible, Slow Traffic Ahead, and Stopped Traffic Ahead, respectively. An overlay with the labeled data points is shown in the plot on the right. The raw data are smoothed using a wavelet transform and then assigned a label based on where is the data are located within the decision tree. If any sensor in a work zone is in either the slow or stopped condition for more than 5 minutes, it is identified as an event.

2. *Number of daytime events:* Number of events that occurred between 6 a.m. and 8.p.m. within each time period.

3. *Average duration of each event* (minutes): Average of all the event durations for the time period.

4. *Median duration of each event* (minutes): Median of all the event durations of the time period.

5. *Average queue length* (miles): All sensors with speeds less than 45 mph during an identified traffic event are identified as in a queue. The lengths of all the sensors within each minute identified as in a queue are summed to calculate the queue length. This measure can be calculated by dividing the time weighted queue length by the summation of all the event durations.

6. *Average maximum queue length of each* (miles): All sensors with speeds less than 45 mph during an identified traffic event are identified as in a queue. The lengths of all the sensors within each minute identified as in a queue are summed to calculate the queue length. Then, the maximum value of the derived queue length is derived for each event. Finally, the average value of all the maximum event queue lengths are calculated for each time period.

7. *Median maximum queue length of each* (miles): All sensors with speeds less than 45 mph during an identified traffic event are identified as in a queue. The lengths of all the sensors within each minute identified as in a queue are summed to calculate the queue length. Then,

the maximum value of the derived queue length is derived for each event. Finally, the median value of all the queue lengths are calculated for each time period.

8. *Max maximum queue length of each event* (miles): All sensors with speeds less than 45 mph during an identified traffic event are identified as in a queue. The lengths of all the sensors within each minute identified as in a queue are summed to calculate the queue length. Then, the maximum value of the derived queue length is derived for each event. Finally, the maximum value of all the queue lengths are selected for each time period.

9. *Percentage of queue > 1 mile:* The duration of time when the queue is > 1 mile divided by the total time any queue was present.

10. *Amount of traffic that encounters a queue* (vehicles): Maximum volume selected among all the sensors within each minute of data. Then, the derived volume is summed within each event. Finally, the volume of all events are summed for each time period.

11. *Percentage of traffic that encounters a queue:* This can be calculated by dividing the amount of traffic that encounters a queue by the total traffic.

12. *Percentage of time that encounters a queue:* This can be calculated by dividing the summation of all the event durations by the duration of time period.

13. *Total vehicle hours of delay when queue is present* (veh-min): The delay is calculated by multiplying the number of vehicles by the travel time deficit for each minute of data and then summing this for all identified events. The travel time deficit is calculated by comparing the travel time calculated from monitored traffic speed against the travel time calculated from a reference speed (speed limit).

14. *Percentage of delay caused by queue:* This can be calculated by dividing the total vehicle hours of delay when a queue is present by the total vehicle hours of delay.

15. *Average vehicle hours of delay per vehicle when queue is present* (veh-min): This can be calculated by dividing the total delay when a queue is present by the amount of traffic that encounters a queue.

16. *95 percentile of delay when there is queue* (minutes): This is found by summing the travel time deficit for all sensors (actual speed vs. speed limit) for each minute of data when an event is identified and then finding the 95^{th} percentile.

17. *Maximum vehicle hours of delay for an event* (veh-hours): The delay is calculated by multiplying the number of vehicles by the travel time deficit for each minute of data. This delay is then summed for each event identified. The maximum vehicle hours of delay for an individual event are then found.

18. *Total time with queue* (minutes): Summation of all the event durations of the time period.

19. *Time weighted queue length* (minutes): All sensors with speeds less than 45 mph during an identified traffic event are identified as in a queue. The lengths of all the sensors within each minute identified as in a queue are summed to calculate the queue length. The summation of average of queue lengths in each event is divided by the duration of the event for each time period.

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