

2012

Integrated risk management for improving internal traffic control, work zone safety, and mobility during major construction

Jay Andrew Mathes
Iowa State University

Follow this and additional works at: <https://lib.dr.iastate.edu/etd>

 Part of the [Civil Engineering Commons](#)

Recommended Citation

Mathes, Jay Andrew, "Integrated risk management for improving internal traffic control, work zone safety, and mobility during major construction" (2012). *Graduate Theses and Dissertations*. 12734.
<https://lib.dr.iastate.edu/etd/12734>

This Thesis is brought to you for free and open access by the Iowa State University Capstones, Theses and Dissertations at Iowa State University Digital Repository. It has been accepted for inclusion in Graduate Theses and Dissertations by an authorized administrator of Iowa State University Digital Repository. For more information, please contact digirep@iastate.edu.

**Integrated risk management for improving internal traffic control, work zone safety,
and mobility during major construction**

by

Jay Andrew Mathes

A thesis submitted to the graduate faculty
in partial fulfillment of the requirements for the degree of
MASTER OF SCIENCE

Major: Civil Engineering

Program of Study Committee:
Jennifer Shane, Major Professor
Charles Jahren
Shauna Hallmark

Iowa State University
Ames, Iowa
2012

Copyright © Jay Andrew Mathes, 2012. All rights reserved.

Dedication

I would like to dedicate my thesis to all of my family members. To my parents Barb and Barry Mathes who have supported me unconditionally in my pursuit of my Masters of Science Degree. To my brother and his wife, Scott and Ashley Mathes, who have always acknowledged my efforts in my pursuit of higher education in both my undergraduate and graduate studies. Finally I would also like to dedicate this to my grandparents Nancy and Jim Dingeman who provided financial and emotional support for me to pursue my goals in higher education.

Without any of these people I would not be the person or the academic that I am today.

Thank you.

Table of Contents

List of Tables.....	v
List of Figures.....	vi
Acknowledgements	vii
Abstract.....	viii
Chapter 1 - Introduction.....	1
Chapter 2 - Literature Review	3
Chapter 3 - Research Methodology.....	11
Qualitative Assessments.....	11
Quantitative Assessments	12
Pilot Project	13
Justification for Mixed Methods Research Methodology	14
Chapter 4 - Data Collection	16
History of the Occupational Health and Safety Administration:	16
Incident Rates	17
OSHA and Iowa OSHA Statistics.....	18
Analysis of OSHA and Iowa OSHA Data Analysis:	22
Summary of OSHA and Iowa OSHA data	26
Comparing National and Iowa Statistics.....	27
Iowa DOT Crash Database	29
Crash Narratives	32
Personal Interviews	34
Ingress and Egress Survey	40
Pilot Project	42
Chapter 5 – Conclusions	45
OSHA and Iowa OSHA.....	45
Iowa DOT Crash Data Base	46
Incident Reports	47
Ingress and Egress Survey	48
Developing the Jobsite Communication Model	49

Summary of Conclusions	52
Research Limitations	54
Possible Future Research	58
Appendices	60
Appendix A - Variables used for Iowa DOT Crash Data Base query	60
Appendix B - Example incident report.....	61
Appendix C – Examples of Innovative Technologies for future implementation.....	63
Appendix D – Example Traffic Control Plans	65
References.....	67

List of Tables

Table 4.1 – Crashes by vehicle type and work zone location.....	31
Table 4.2 – Table of example sample taken for crash narratives.....	32
Table 4.3 – Summary of categorization of crash narratives.....	33
Table 4.4 – Summary of categorization of Ingress and Egress Survey for “Closed” and “Open” work zones.....	42

List of Figures

Figure 3.1 - Research Method Diagram.....	15
Figure 4.1 – Graph of Iowa Annual Employment for Highway, Street, and Bridge Construction.....	18
Figure 4.2 – Graph of total recordable cases for Highway, Street, and Bridge construction.....	19
Figure 4.3 – Graph of cases with days away from work, job restriction, or job transfer for Highway, Street, and Bridge Construction.....	20
Figure 4.4 – Graph of cases with days away from work, job restriction, or job transfer for Highway, Street, and Bridge Construction.....	21
Figure 4.5 – Linear fit for total recordable cases rate (National and Iowa).....	23
Figure 4.6 – Linear fit for total recordable cases with days away from work, job restriction, or job transfer, (National and Iowa).....	24
Figure 4.7 – Linear fit for other recordable cases (National and Iowa).....	25
Figure 4.8 – Illustration of construction “Zones” as defined by the Iowa DOT.....	30
Figure 5.1 - Example jobsite communication model.....	50
Figure 5.2 - Differing conditions communication model.....	51
Figure 5.3 - Communication model for major equipment delivery.....	52

Acknowledgements

I would like to take this opportunity to thank all of my committee members. First I would like to thank Dr. Jennifer Shane and Dr. Kelly Strong for their interest in me to work for them as graduate research assistant. I would also like to thank Dr. Charles Jahren and Larry Cormicle for their interest in me to work for them as a Graduate Teaching Assistant. Their work and support allowed for me to pursue a Master of Science in Civil Engineering at Iowa State University.

My committee members include Dr. Jennifer Shane, Dr. Charles Jahren, and Dr. Shauna Hallmark. Each member of this committee has been outstanding in their help and insights to the construction industry and all played a vital role in the completion of my education at Iowa State University.

I would also like thank all of the members of the Technical Advisory Committee who volunteered to take time out of their professional and personal lives to contribute to this research project. Their expertise was essential to the success of this project and served as the research team's expert panel for advice and insight

Abstract

Highway construction is among the most dangerous industries in the United States. Internal traffic control design along with how construction equipment and vehicles interact with the traveling public has a significant effect on how safe a highway construction work zone can be. An integrated approach is taken to address safety issues and work zone mobility should be considered from as many personnel as possible, ranging from roadway designers to construction laborers and equipment operators. A look at crash data, Occupational Safety and Health Administration publications in conjunction with personal interviews as well as other types of qualitative data are analyzed.

Chapter 1 - Introduction

Construction work zones are among the most dangerous places to work in any industry in the world. This is because of many different factors that all add up to make for a disproportionate number of accidents, injuries, and property damage, and other losses in the construction industry when compared to other industries. Construction safety practices are essential to preventing loss on a jobsite and should be monitored during every stage of the project.

Regulatory agencies such as the Occupational Safety and Health Administration have efforts to prevent unsafe work conditions, but regulatory agencies can only inspect a small percentage of jobsites due to the lack of resources. These agencies have expanded to the state level within the last 20 years which helps to lend a piece of the picture that will be explored. Local Departments of Transportation are also tasked with keeping statistical data in order to communicate trends within their own states and districts.

Work zone mobility has a major effect on the safety of any highway construction jobsite and continues to be a topic of conversation for the State of Iowa, Iowa Department of Transportation officials, utility companies, and contractors. On highway construction projects there is often far less control over the jobsite and there is much more exposure to traffic and heavy equipment than on other types of construction sites. The safety of workers and project work zones are affected by nearly every person who is involved in the project. Managers and officials are tasked with developing site layouts and laborers and operators are held responsible for executing those plans. Without efforts from every level of individual in the construction process, safety may be compromised.

To increase safety efforts, many perspectives must be considered in order to paint a well-rounded picture describing what is actually happening on jobsites. A single set of data, in this case, will not suffice because of the nature of a highway construction site. It is very difficult to normalize data, make inferences on small sample sizes, and base policy on any one set of findings. To help manage this problem various types of quantitative as well as

qualitative assessments will be performed. Any common conclusions that are discovered between multiple assessments allows for stronger conclusions, especially if a quantitative analysis is able to support a qualitative claim by experts.

Work zone safety, mobility, and internal traffic control are addressed by nearly every state Department of Transportation and many policies are available for review in the Federal Highway Administration's (FHWA) databases. Even with the accumulation of all of this information, highway construction is still one of the most dangerous industries in the United States.

This study hopes to address the preceding issues in highway construction. The purpose of this study is to help reduce the frequency and severity of incidents, identify areas of greatest concern for construction operations, and to identify best practices within the highway construction industry.

Chapter 2 - Literature Review

To serve as a one of the support systems for current and future studies, a literature review must be performed. Assessments of current policies and procedures can be used both to compare current policies and to assess whether similar programs can be successfully implemented in Iowa. Certain procedures and technologies do not make sense to use in Iowa due to size of projects, sizes of typical districts, and how they interact with other states, but many can be considered in future implementation if areas see certain amounts of population growth. Innovative technologies as well as other articles which highlight principles of work zone mobility are published by the Federal Highway Administration and are available for public viewing. General policies that are practiced by other states may have the biggest impact on what can be immediately be implemented to help work zone mobility and internal traffic control.

2.1 - Internal Traffic Control and Worker Safety

The Roadway Safety Alliance (RSA) cited that the number one cause of worker fatality in the work zone is the backing up of vehicles. There are several reasons why this is occurring. The RSA cites that the included safety measures such as back up alarms are not always able to prevent incidents with pedestrian workers. This can be caused by alarms that are not working, or a noisy jobsite that has alarms on several pieces of equipment and workers cannot identify where vehicles are within their vicinity because of the multiple sound sources. (The Roadway Safety Alliance, 2008)

The Laborers' Health and Safety Fund of North America (LHSFNA) reported that highway construction had high rates of fatal injuries in highway construction compared to other construction activities and to all other industries. This same report also found that backing equipment, particularly dump trucks, accounted for half of the fatalities of pedestrian workers in work zones (Laborers Health and Safety Fund of North America, 2004). In Iowa, there are on average 6.5 deaths per year, 136 injury crashes, and 224 property damage only

crashes, totaling an average of 366 work zone crashes per year. Ninety percent of Iowa work zone fatalities are motorists (Shane et al., 2009)

Effective internal traffic control plans (ITCPs) may help prevent deaths and injuries inside the work zone. The LHSFNA explored the dangers of internal hazards in work zones. They found that just as many workers were being injured or killed by incidents within the work zone as they were by the traveling public. (Laborers Health and Safety Fund of North America, 2004) When developing an internal traffic control plan, the following should be considered:

- 1.) Reduce the need for vehicles to back up
- 2.) Limit the access points to the job site or work zone
- 3.) Establish work zone layouts according to the type of equipment involved
- 4.) Provide signs within the work zone to guide workers, equipment and trucks
- 5.) Design buffer spaces to protect pedestrian workers from errant vehicles or equipment

The Roadway Safety Alliance also in their 2008 publication helped to develop a simple template for developing traffic control plans. Included in it are example internal traffic control plans for effectively using spotters, example signage of what types of signage should be used within the work zone, and also plans that specify exact “No Pedestrian Zones” to help prevent incidents between workers that are on the ground and mobile equipment. Not only are there “No Pedestrian Zones” included in these plans, several plans are shown with “No Motor Vehicle” signs as well to help designate safe areas for pedestrian workers.

2.2 - Developing the Internal Traffic Control Plan

The responsibility of developing the internal traffic control plan lies with the contracting agency on the project. The following guidelines for developing an ITCP include the following:

- 1.) The ITCP is developed by one or more members of the contractor’s staff and should be part of the project’s overall safety plan. It should be prepared after the contract is awarded but prior to the start of construction.

- 2.) The safety officer, if qualified, should be in charge of the development of the ITCP.
- 3.) This officer should meet the OSHA requirements of a “competent person.” (Graham, et al. 2005)

Establishing personnel and their responsibilities, along with identifying common strategies that can be used on projects, is very important and can lead to consistent internal traffic control planning. However, on significant multi-year projects a much larger framework must be developed to ensure safe and consistent practices.

Significant repair and replacement projects in Oregon have lead the Oregon Department of Transportation (ODOT) officials to re-think the process of developing traffic management plans (TMP's) for their highway and bridge construction projects. Since there was a large overhaul of highway systems that would affect major travel routes, freight travel became a large priority in ODOT's traffic management plans. In the past, ODOT first designed projects then addressed traffic control and mobility. In their new approach, ODOT considers mobility conflicts in the same way that it addresses environmental issues, by addressing problems throughout the design process (Oregon Department of Transportation, 2011).

TMP's have been developed on three different levels to address mobility problems:

- 1.) Program-Level TMP - Address traffic management at higher levels and provides a framework for the Corridor-Level TMP's.
- 2.) Corridor-Level TMP – Traffic plans that are developed for specific key freight and major travel routes. If delay thresholds are exceeded, major reviews of staging, scheduling, and traffic management strategies are conducted.
- 3.) Project-Level TMP – Used to address problems on single projects and are developed based on individual project details. Project-level TMP's are also used to coordinate multiple projects in a localized area.

The next step up in evaluating internal traffic control and work zone mobility is to identify practices and research within policies and procedures of governing bodies. Items such as processes in internal traffic control changes, addressing concerns and updating the

Manual on Uniform Traffic Control Devices, and work zone safety and mobility reviews are the key to addressing an ever-evolving highway construction zone.

Several provisions were made to the Manual on Uniform Traffic Control Devices (2003) to address mobility concerns. Included in the provisions were “E. Activity Area – Planning the internal work activity area to minimize backing-up maneuvers of construction vehicles should be considered to minimize exposure to risk.” and “F. Worker Safety Planning- A competent person designated by the employer should conduct a basic hazard assessment for the work site... (to) determine whether engineering, administrative, or personal protection measures should be implemented.” These provisions were made to address risks that were not specifically identified with regards to internal traffic control and worker mobility already (Midwest Research Institute, 2005). A competent person is defined by ODOT and OSHA alike in that they should be "one who is capable of identifying existing and predictable hazards in the surroundings or working conditions which are unsanitary, hazardous, or dangerous to employees, and who has authorization to take prompt corrective measures to eliminate them" (OSHA 2012)

A six step Internal Traffic Control Plan development guide was also developed by the Midwest Research Institute. The six steps include:

- 1.) Review Contract Documents and Model Plans
- 2.) Determine Construction Sequence and Choose Phases Having Site-Specific internal traffic control plans
- 3.) Draw the Basic Work Area Layout
- 4.) Plot Pedestrian and Vehicle Paths
- 5.) Locate Utilities, Storage, and Staging Areas
- 6.) Prepare internal traffic control plan notes

Also conducted in the 2005 study were observations of paving operations. Conclusions derived from these operations include the following:

- 1.) The internal traffic control plan is a graphical method to inform vehicle operators and pedestrian workers of hazards inside the work area. The provision of an

internal traffic control plan would have reduced hazards and observed conflicts at all four paving sites observed.

- 2.) A competent person was not available during all paving operations. The safety officer was either absent or visited the site for a very short time.
- 3.) Safety plans were generic and not specific to any of the sites
- 4.) Truck drivers were often confused about how to access the site and most could not communicate with spotters, forepersons, or plant operators.
- 5.) At one site, material trucks and other services vehicles operated at relatively high speeds, even at night with little illumination.
- 6.) There was no reliable method of controlling the rate of truck arrivals at the work site.
- 7.) Lock-out, tag-out procedures were not always observed.

The Midwest Research Institute developed this guide to address concerns in asphalt paving but also can be applied to other highway work zone operations.

As developments occur and concerns are addressed on a national scale, individual states' Departments of Transportation are always implementing new technologies to help improve work zone interactions. A few of the most innovative technologies that have been very effective are ones that help contractors and utility workers coordinate work.

The City of Baltimore, Maryland has implemented a software-based system to help reduce impacts on construction projects that affect the traveling public's right-of-way. The system they used was implemented over a two year period and provides real-time information on infrastructure projects around the city. (City of Baltimore, 2011) Included in the software are maps that show key details such as scope, location, schedule, costs and major points of contact for individual projects. Three major stakeholders were included when addressing the needs of the system: They Mayor's Office, the City of Baltimore staff, and utility companies.

Benefits that were found in the implementation of this included the following:

- 1.) Stakeholder engagement was improved – awareness of each of the parties involved in all of these projects was vastly increased. Since information is proactively provided, there is less wasted time in trying to make individuals aware of project information.
- 2.) Awareness of project impacts and enhancement of TMP's – The city of Baltimore is now able to better predict impacts of construction because of the early identification of project details.
- 3.) Increased Data Quality – Stakeholders are willing to contribute data from their own systems to better manage Baltimore's infrastructure network
- 4.) Longer Pavement Life – Reduction of the number of pavement cuts has lead to an increase in pavement quality. Significant cost savings have been realized in the form of better coordinated work which allows for more seamless production.

As of October 2011, the New York City Department of Transportation (NYC DOT) began using an online construction mapping system, guidance manuals, and incentive programs to help improve coordination of construction (New York City Department of Transportation, 2011). Agreements were established on the monthly sharing of data between contractors, utilities, and the city. This data includes: All active NYC DOT street excavation permits, NYC's list of "protected streets", and the NYC DOT's roadway resurfacing schedule which includes short term utility needs and long-term utility project schedules. The information is shared on the city's public online map called "NYCityMap" which allows utility companies and contractors alike to identify current construction projects which allows them to better coordinate work.

The Pennsylvania Department of Transportation is implementing similar technologies that are being used in Baltimore and New York City as well. Allegheny County was the first in the state to use "mapping" of construction projects to help coordinate efforts in both construction and utility work. This system has helped warn DOT officials of potential conflicts of co-current construction projects and has also helped prevent many instances of re-work. This software is called "Envista" and is currently used in Baltimore, Colorado Springs, Sacramento, and Providence (Envista, 2009).

2.3 – Iowa DOT Work Zone Safety and Mobility Process Review

The purpose of this process review was to address potential concerns with Iowa DOT Work Zone Policy with regards to 630 Subpart J (Work zone Safety and Mobility), 630 Subpart K (Temporary Traffic Control Devices) and 634 (Worker Visibility). Included below are the findings of the review and their proposed solutions:

- 1.) After reviewing existing TMPs, it appears some district and central office staff need assistance in developing effective Transportation Management Plans for significant projects.

Solution: The Division Office requested assistance from the Office of Transportation Operations and training workshops were conducted May 18-19 in eastern Iowa and May 20-21 in central Iowa.

- 2.) After receiving TMPs from district offices, it appears that there is no format for Iowa DOT staff to aid in the development of comprehensive Transportation Management Plans for significant projects.

Solution: A draft TMP template will be piloted on projects in December 2010 with a final template in place by April 2011.

- 3.) Some TMPs were created but the electronic copies were not able to be located when requested. The Iowa DOT does not have a standardized electronic storage location for significant project files, including TMPs and supporting documentation.

Solution: The Information Technology Division will add folders under the project directory folders on the local area network (W: drive) for significant project files, including TMPs and supporting documentation by January 2011.

- 4.) While exceptional training is provided to those who install, maintain, and inspect temporary traffic control in the field, training for those who design temporary traffic control plans is not available.

Solution: ATSSA's Traffic Control Supervisor course will be brought in for Iowa DOT employees and others who instruct the work zone safety workshops by January 2011. ATSSA's Traffic Control Design Specialist course will be brought in from Iowa DOT staff and consultants involved in the design of temporary traffic control plans by May 2011.

Suggested resolutions to these factors were also identified and were to be implemented by early to late 2011. The FHWA Iowa Division has worked closely with the Iowa DOT in resolving the above issues. The final report was completed on September 7, 2010. In a 2011 survey of 52 States/divisions, 85 percent had conducted a similar work zone process review since 2009.

The literature review of this project reveals that there are many different ways to go about mitigating risk on highway construction projects. On a project level, workers and operators can train to be more aware of potentially dangerous situations. On a city planner level, construction zones can be mapped and tracked to help mitigate effects of conflicting work zones. The focus of this research project is to help mitigate risk on a project and managerial level. Policies and planning to help reduce risk and safety related problems, on these levels, are of primary concern.

Chapter 3 - Research Methodology

The research methodology used in this project is rather unique in that it implements a variety of types of research. Within this study three types of qualitative assessments will be performed along with two types of quantitative analyses. The qualitative assessments include Technical Advisory Committee meetings, personal interviews, and an ingress and egress survey. The quantitative assessments performed in this study include observational statistics on incident reports from the Iowa Department of Transportation Crash Database, and linear modeling and an analysis of variance test for Occupational Safety and Health Administration (OSHA) and Iowa OSHA incident statistics.

3.1 - Qualitative Assessments

Highway construction is unique in that there are many human factors that must be considered when planning for construction. Almost every highway construction site is tasked with interfacing work with the traveling public. The sharing of highway space between passenger vehicles and construction activities is cause for many of the concerns highway professionals must handle.

To form a platform to conduct research on internal traffic control, work zone safety, and mobility, a Technical Advisory Committee was formed. The following Iowa DOT officials and employees were included: Dan Sprengler, Doug Clark, Mark Jackson, Mark Bortle, John Smythe, Dean Herbst, Dwight Jenkins, and Roxanne Seward. These individuals are considered experts in highway construction and maintenance operations and represent various levels of management and also include local district managers and engineers. Also included in the Technical Advisory Committee were three representatives from contracting agencies. The persons included are: Steve Jackson, President of Cedar Valley Corp; Craig Hughes, Vice President of Field Operation for Cedar Valley Corp and Robert Cramer, President of Cramer and Associates. The Technical advisory committee served to support

the research team in initial research direction, provide further insight into highway construction, review initial findings, and provide feedback. The committee was gathered on two separate occasions and was consulted throughout the project on incremental findings of this study.

Personal Interviews were conducted with construction personnel ranging from Iowa DOT officials to heavy equipment operators. The persons that were interviewed include Jeff Koudelka, Vice President of Iowa Plains Signing Incorporated; Jason Hankins, Project Manager for Cedar Valley Corporation; Roxanne Seward, Traffic Technician District 3 Iowa DOT; and Dave Webb, Plant Operator for Central Iowa Ready Mix. These individuals were identified by the Technical Advisory Committee as relevant sources to provide insight to jobsite conditions and how they relate to work zone safety and mobility. The types of interviews conducted were Informal Conversation Interview and General Interview Guide. These two interview types were best suited due to the range of construction experience of the persons interviewed and the differing topics that were covered in each interview. Both the Standardized, Open-Ended Interview and Closed, Fixed-Response Interview types were not used since it was not intended to compare results to asking a standardized set of questions. These two styles of interview are also not conducive to follow up questions which were essential in the interview process.

3.2 - Quantitative Assessments

Human factors, in certain instances, can be measured and looked at qualitatively as well. The Iowa DOT maintains a crash database in which reporting officers from each jurisdiction submit an incident form from each crash that is responded to. Each incident form that is filed has a multitude of variables that are considered when describing the incident. Database variables that were considered relevant to this study include vehicle configuration, if the incident was work zone related, and the location of the incident within the work zone. These variables and their descriptions are included in Appendix A. Statistics were broken down into a spreadsheet of each variable according to its "Case Number" and a 10 percent random sample of the cases was further investigated by reviewing the narratives of the sample cases to look for any trends that were not identified in the raw statistics alone.

The narratives associated with each Case Number provide a detailed description of the incident. Items that cannot be conveyed in the numerical data are included. Some examples of items that are included in these narratives are relative locations of vehicles, locations of exit and entrance ramps, and any other descriptive information that the reporting officer feels is important to the case. This information then can only be used as a qualitative or descriptive statistic and like information provided by our Technical Advisory Committee should only be used to guide further investigations.

Data that was published by the Occupational Safety and Health Administration (OSHA) and Iowa OSHA was also carefully considered in this study. Two sets of data are published by OSHA and Iowa OSHA each year. Included in the first set are recordable case counts for each type of industry and included in the second set are incident rates for each type of industry. The incident rates are used in this study because they display a relative statistic that can be compared to national rates and rates that are achieved by other states.

All of the statistical data considered in this study was obtained by means of empirical research. The most recent available data for OSHA and Iowa OSHA was 2010 and for the Iowa DOT crash database, 2011. No means of theoretical research was considered in this study.

3.3 - Pilot Project

A pilot project was also used in this study. The goal of the pilot project was to gain more insight as to how changes are performed within traffic control, how work zone mobility concerns are addressed and how these items fit the “best practices” that are identified throughout this study. The pilot project that was identified in this project is the Interstate 29 Expansion and Improvement project that is located in Sioux City, Iowa. Overall the project includes widening the current interstate system, replacing several entry and exit ramps, and replacing several bridges. The main focus of our study covers the Segment 1 portion that includes the widening of the current interstate system from four lanes to six lanes.

3.4 - Justification for Mixed Methods Research Methodology

A mixed methods approach is chosen given that there are many difficulties that were encountered when setting up avenues to gather information that would help produce an outline of how activities on highway construction affect safety. One method of collection for a single research topic is to gather information reported by highway construction contractors on incidents to insurance providers to determine the interactions within the construction site. However, this is not a practical solution for this research provided that construction companies and insurance companies are often hesitant to report this type of information because of its sensitive nature. Therefore, for this project broader statistics, such as gathering OSHA information, must be relied upon in conjunction with qualitative data such as personal interviews or analysis of specific incident reports.

Data from within the work zone on the construction site is provided by OSHA and Iowa OSHA statistics. This information provides the qualitative data and supports the other statistical analysis. The OSHA and Iowa OSHA data provides information on all accidents that happen within a jobsite. These reported accidents include those that involve construction equipment and vehicles as well as falls, electrocution, and other jobsite accidents. With the Iowa DOT Crash Database, information about the traveling public can be compiled by the task of a database query with selected variables. A major gap, however, surfaces in how the traveling public interactions directly with construction vehicles. As it is later detailed in this study, a survey was designed to address concerns with ingress and egress areas in work zones. These areas were to be the final piece of the puzzle to show how internal traffic control, safety, and mobility could be addressed.

Due to limitations of the quantitative data the research also relies on qualitative assessments, a questionnaire, and TAC meetings to support the quantitative assessments. The mixed methods research methodology was best suited to address the concerns that were associated with the quantitative data and were implemented as such in this study.

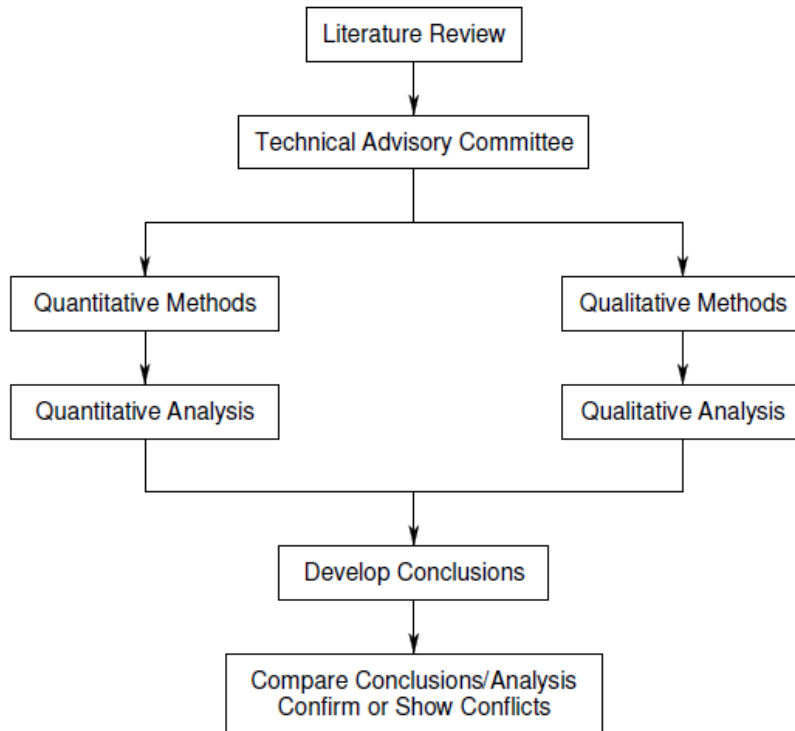


Figure 3.1 – Research Method Diagram

The overall research methodology is summarized in Figure 3.1. This figure is a method diagram that illustrates which tasks were performed and in what order. Qualitative and quantitative analyses were performed simultaneously with the intention of using each type to confirm or deny claims from the other method of research. The qualitative research methods in this study include OSHA and Iowa OSHA statistics and analysis along with Iowa DOT Crash Database queries and analysis. Qualitative research methods include the analysis of crash narratives, personal interviews with a range of construction personnel, an ingress and egress in construction work zones survey, and the pilot project.

Chapter 4 - Data Collection

Data collection or compilation is essential to a research project and must be analyzed carefully. Data can be presented in many different ways as explained in the research methodology. The quantitative data in this study includes descriptive statistics from the Iowa DOT Crash Data base, statistics released by the Occupational Safety and Health Administration (OSHA), and statistics released by Iowa OSHA. Qualitative data in this chapter include Technical Advisory Committee reviews, personal interviews, ingress and egress survey results, and crash incident narrative summaries.

Also within any study, a thorough data analysis must be performed to ensure that conclusions can be provided and that inferences about data can either be confirmed or rejected. Some of the data that is included in this study can be statistically analyzed using typical analysis of variance testing and others by observational comparison. Items that are addressed in both the TAC meetings and personal interviews can only be used to confirm or show difference between perception in work zone safety and mobility and statistical findings.

Statistical results that coincide with claims by either the expert panel or claims made during personal interviews offer strong evidence of patterns in highway construction safety and mobility. The claims identified, when backed by both statistics and expert knowledge, are said to be triangular in nature. However, when encountering statistical evidence that is contrary to expert panel or interview claims, an anomaly occurs.

4.1 - History of the Occupational Health and Safety Administration:

OSHA was first established in 1971 in an effort to reduce workplace incidents, deaths, and injuries. In 1972, OSHA approved South Carolina, Montana, and Oregon to adopt and enforce the agency's standards in their states. Shortly after, in 1973, construction standards were adopted to protect construction workers operating electric power transmission and distribution equipment, aerial lifts, and helicopters. During the 1980's states and territories granted final approval to form their own state's OSHA program within the decade included the Virgin Islands, Hawaii, Alaska, Arizona, Iowa, Indiana, Kentucky, Maryland,

Minnesota, North Carolina, South Carolina, Tennessee, Utah, Virginia, and Wyoming. Incident rates for Iowa OSHA industry data began being reported in 1996 and the latest data released is from 2010.

4.2 - Incident Rates

OSHA produces annual safety reports on nearly every type of industry in the United States and uses Incident Rates to serve as a baseline for states to compare to national averages. These national averages incorporate all hours worked by all states and are calculated by the following formula:

Incidence rates represent the number of injuries and illnesses per 100 full-time workers and were calculated as: $(N/EH) \times 200,000$ where:

N = number of injuries and illnesses

EH = total hours worked by all employees during the calendar year

200,000 = base for 100 equivalent full-time workers (working 40 hours per week, 50 weeks per year).

4.4 - OSHA and Iowa OSHA Statistics

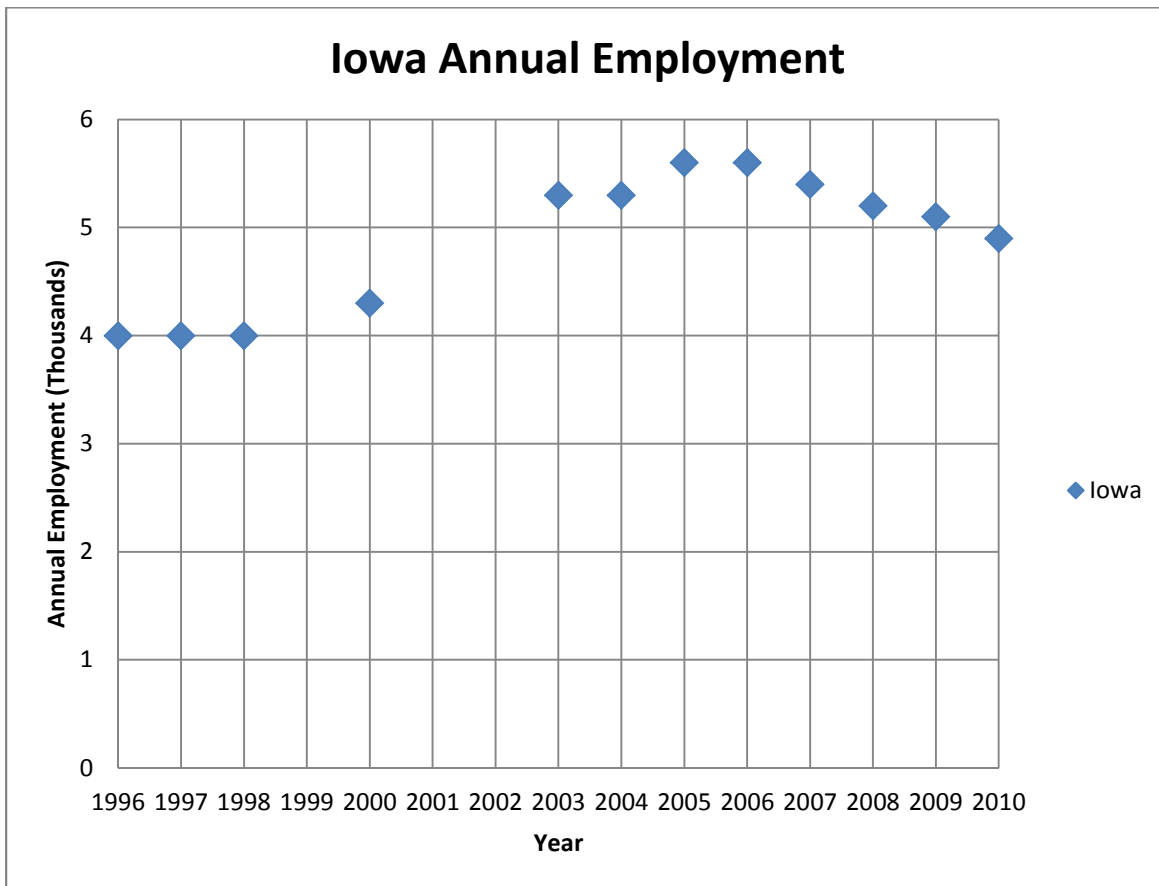


Figure 4.1 – Graph of Iowa Annual Employment for Highway, Street, and Bridge construction

Figure 4.1 shows the annual employment of “Highway, Street, and Bridge construction” data that is released by Iowa OSHA from 1996 to 2010. The data is reported in thousands of hours. Annual employment is an aggregation of all construction operations within the state of Iowa that are not considered building or other civil construction.

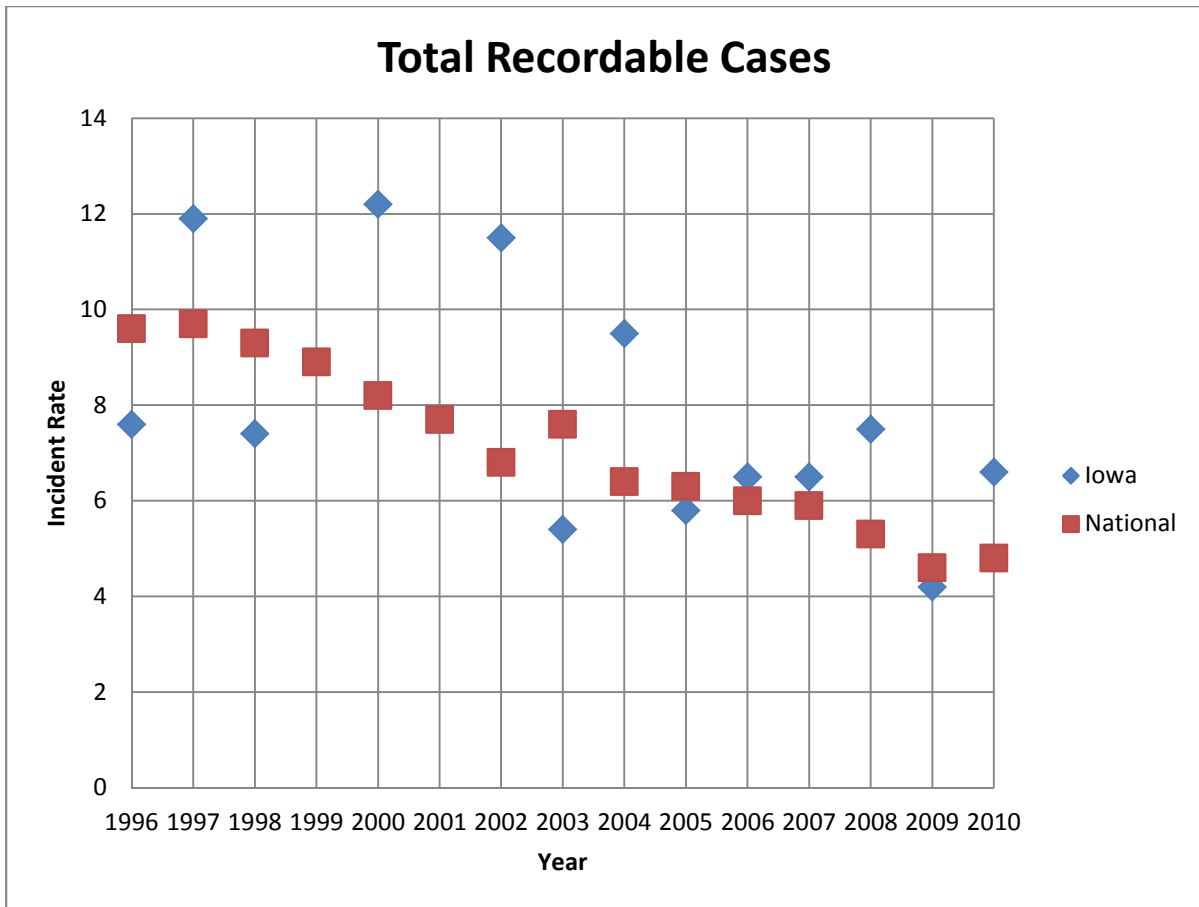


Figure 4.2 – Graph of total recordable cases for Highway, Street, and Bridge construction

Figure 4.2 compares incident rates for total recordable cases in each given year. Items that are considered recordable by OSHA and Iowa OSHA standards include incidents involving death, loss of consciousness, days away from work, restricted activity or job transfer, and any incident that requires medical treatment beyond first aid. Cases that involve an incident of death are not included in Figure 4.2.

Incidence rates represent the number of injuries and illnesses per 100 full-time workers and were calculated as: $(N/EH) \times 200,000$ where:

N = number of injuries and illnesses

EH = total hours worked by all employees during the calendar year

200,000 = base for 100 equivalent full-time workers (working 40 hours per week, 50 weeks per year).

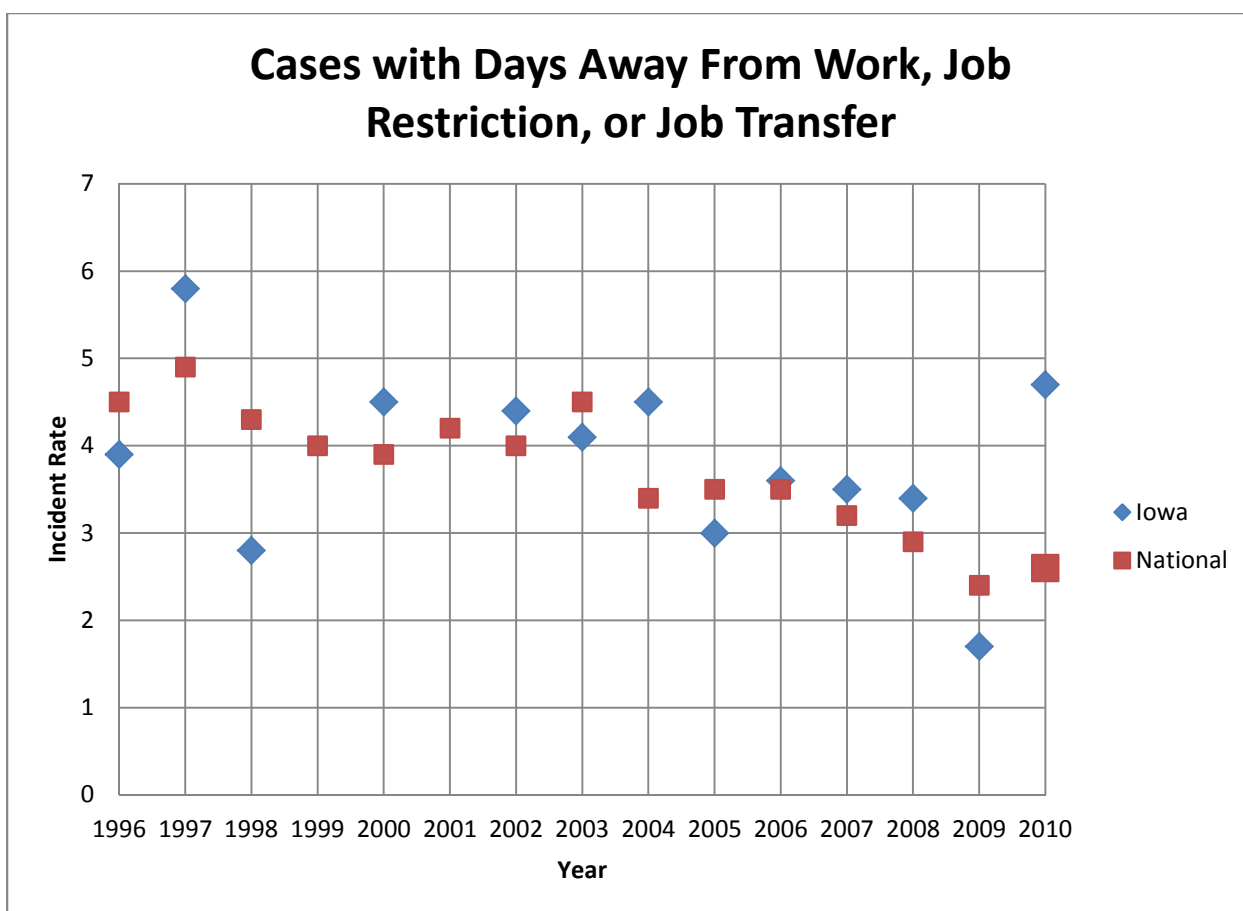


Figure 4.3 – Graph of cases with days away from work, job restriction, or job transfer for Highway, Street, and Bridge construction

Figure 4.3 compares incident rates for cases with days away from work, job restriction, or job transfer in each given year. Cases that involve an incident where a death occurred are not included in Figure 4.3.

Incidence rates represent the number of injuries and illnesses per 100 full-time workers and were calculated as: $(N/EH) \times 200,000$ where:

N = number of injuries and illnesses

EH = total hours worked by all employees during the calendar year

200,000 = base for 100 equivalent full-time workers (working 40 hours per week, 50 weeks per year).

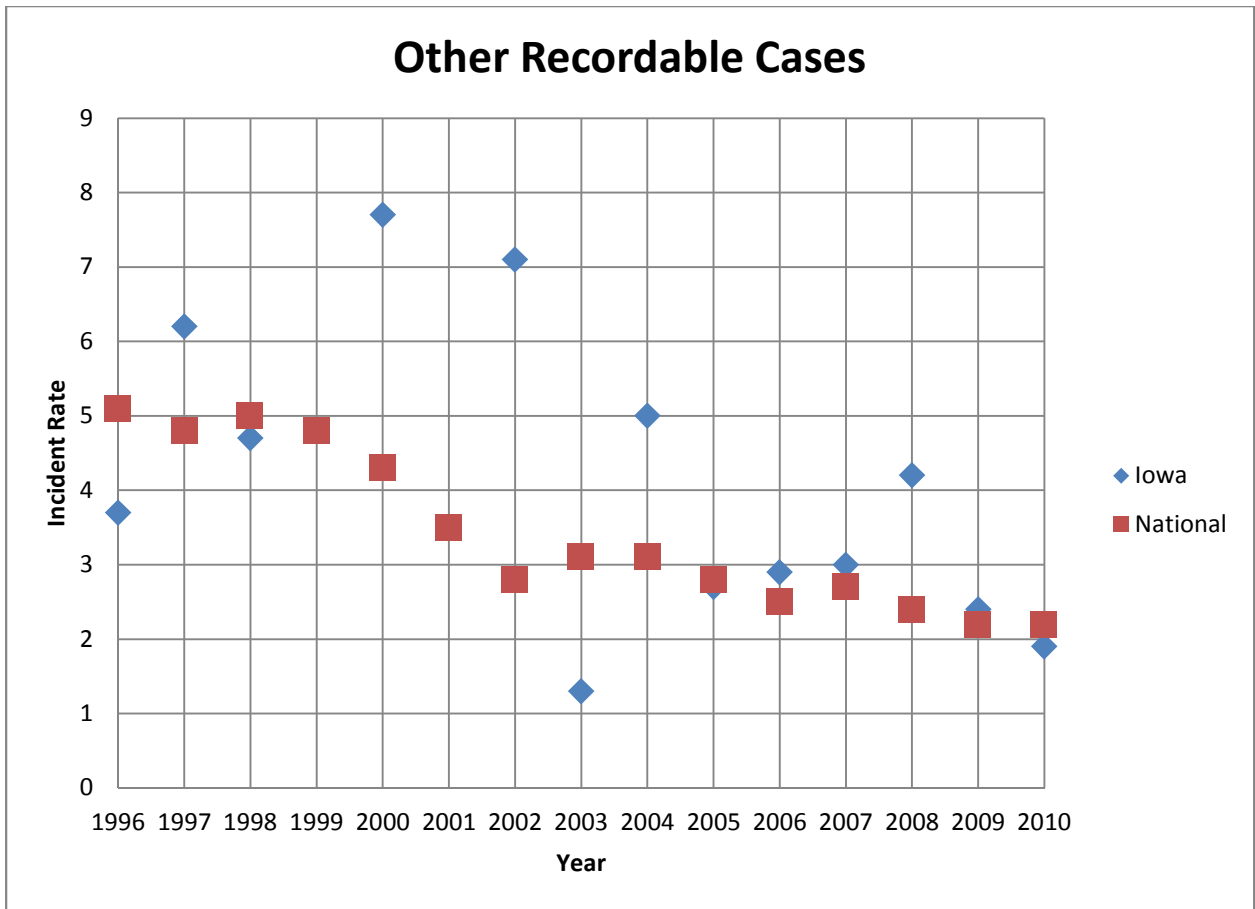


Figure 4.4 – Graph of cases with days away from work, job restriction, or job transfer for Highway, Street, and Bridge construction

Figure 4.4 compares incident rates for “Other Recordable Cases.” These items include incidents whose injuries or illnesses are not severe enough for job restriction, job transfer, or days away from work.

Incidence rates represent the number of injuries and illnesses per 100 full-time workers and were calculated as: $(N/EH) \times 200,000$ where:

N = number of injuries and illnesses

EH = total hours worked by all employees during the calendar year

200,000 = base for 100 equivalent full-time workers (working 40 hours per week, 50 weeks per year).

It is important that Iowa uses this metric effectively to help reduce incidents within its own boundaries. If statistics such as these are ignored, it can be detrimental to the identification of major problems within the highway construction industry in Iowa. As the national standard in safety enforcement, these statistics provide the best snapshot of how each state is doing on the whole with regards to safety in industry.

4.5 - OSHA and Iowa OSHA Data Analysis:

Data collection for “Highway, Street, and Bridge Construction” began in 1996 for Iowa OSHA and most recent data dates to 2010. This data set includes information on incident rates for total recordable cases; total cases with days away from work, job restriction, or job transfer; and other recordable cases. Linear regression models were performed for each of these categories to compare Iowa incident rates to National incident rates. A 95 percent confidence interval was performed for both the regression fit and the individual value range. It must be noted that Iowa data is included in the national data. Since it represents an extremely small percentage of the total national annual employment, it was determined that it would not affect the national linear models. Linear models for this analysis area are appropriate because of the ability to explain variance in the coefficient of determination statistic. Because of the ability of the linear model to account for variation, it is effective in the analysis.

As seen in Figure 5.1 through Figure 5.3, a 95 percent confidence interval is displayed for both the model and the individual value ranges. The darker ranges represent the Linear Model confidence interval where-as the lighter ranges represent the individual value confidence ranges. The model confidence interval can be interpreted in that the actual predictive linear model has a 95 percent chance of falling within the range provided. The individual value confidence interval can be interpreted in that actual individual values for incident rates for any given year have a 95 percent chance of falling within the range provided without being considered outliers.

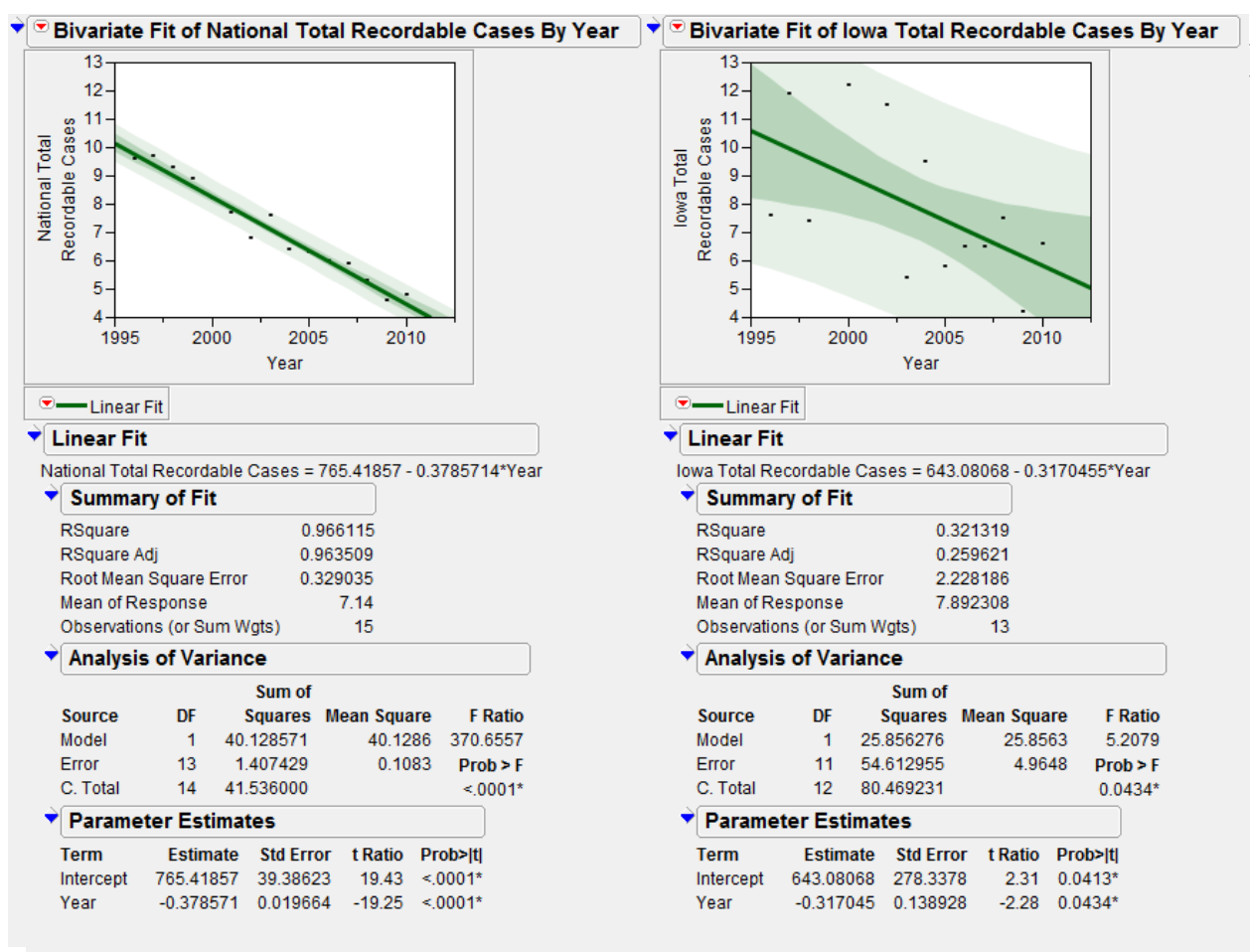


Figure 4.5 – Linear fit for total recordable cases rate (National and Iowa)

Figure 4.5 includes the JMP version 8 output of an Analysis of Variance test as well as a linear regression model for National and Iowa rates for “Total Recordable Cases”. JMP is statistical analysis software that is used in this study to perform both the linear model analysis and analysis of variance tests. When analyzing the National yearly rates, there is a clear downward trend with a very tight confidence interval. The coefficient of determination of the national data is extremely high at 0.966 which means that the linear model of $[Recordable\ Case\ Rate = (756.42) - (0.379 * Year)]$ is a very accurate and predictive model. Iowa yearly rates, however, are not as readily able to predict an accurate yearly rate for “Total Recordable Cases”. With an R-Square value of 0.321, the model is a very poor predictor of “Total Recordable Cases”. This model also has a Standard Error that is seven

times as large as the national rate. Because of this, there is a large overlap that it cannot be said that the two models are significantly different.

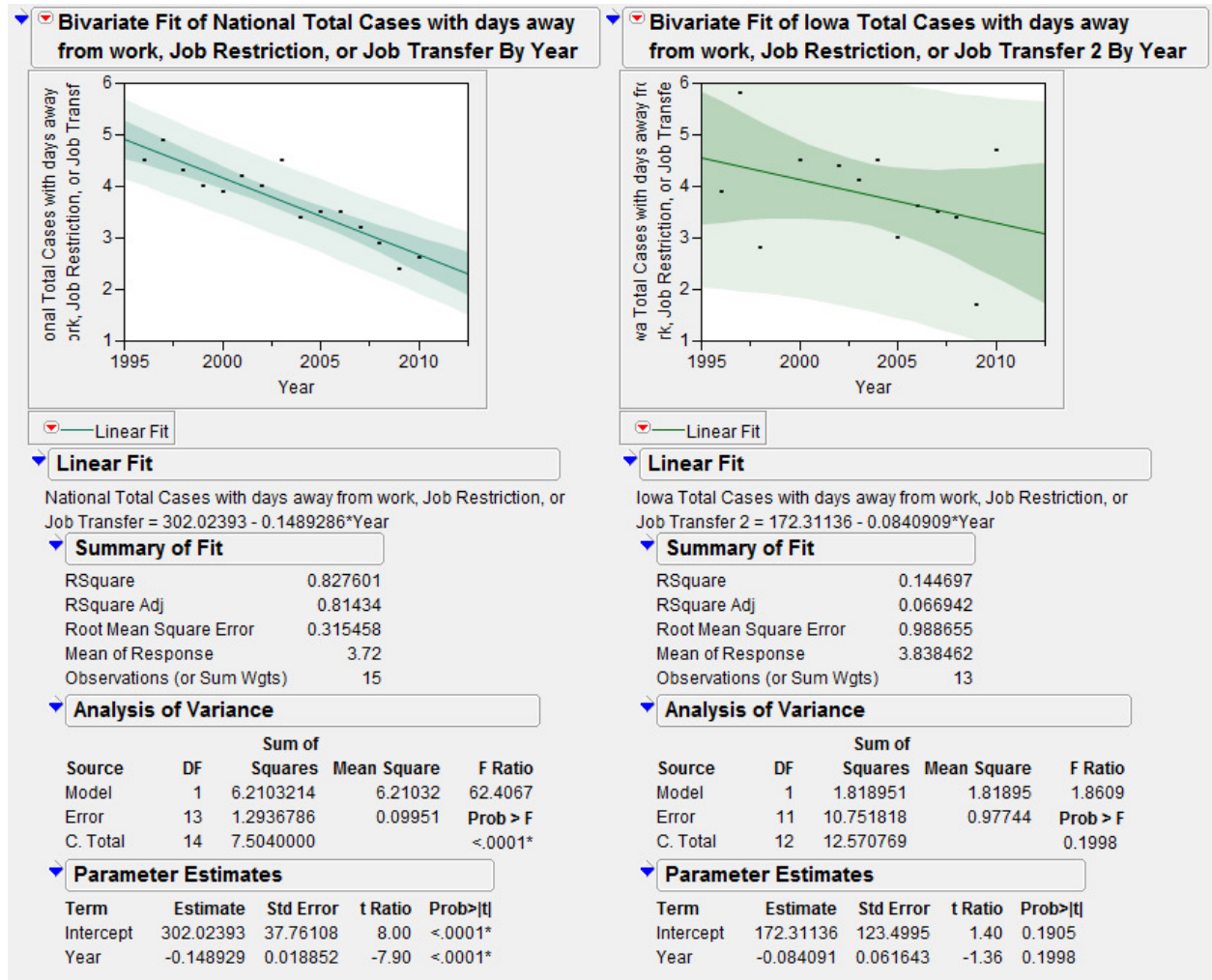


Figure 4.6 – Linear fit for total recordable cases with days away from work, job restriction, or job transfer, (National and Iowa)

Figure 4.6 includes the JMP version 8 output of an Analysis of Variance test as well as a linear regression model for National and Iowa rates for “Cases with Days Away From Work, Job Restriction, or Job Transfer”. When analyzing the National yearly rates, there is a clear downward trend with a very tight confidence interval. The coefficient of determination of the national data is high at 0.828 which means that the linear model of $[\text{Recordable Case Rate} = (302.02) - (0.149 * \text{Year})]$ is an accurate and predictive model. Iowa yearly rates,

however, are not as readily able to predict an accurate yearly rate for “Cases with Days Away From Work, Job Restriction, or Job Transfer”. With an R-Square value of 0.145, the model is a very poor predictor of “Cases with Days Away From Work, Job Restriction, or Job Transfer”. This model also has a Standard Error that is three times as large as the national rate. Because of this, there is a large overlap that it cannot be said that the two models are significantly different.

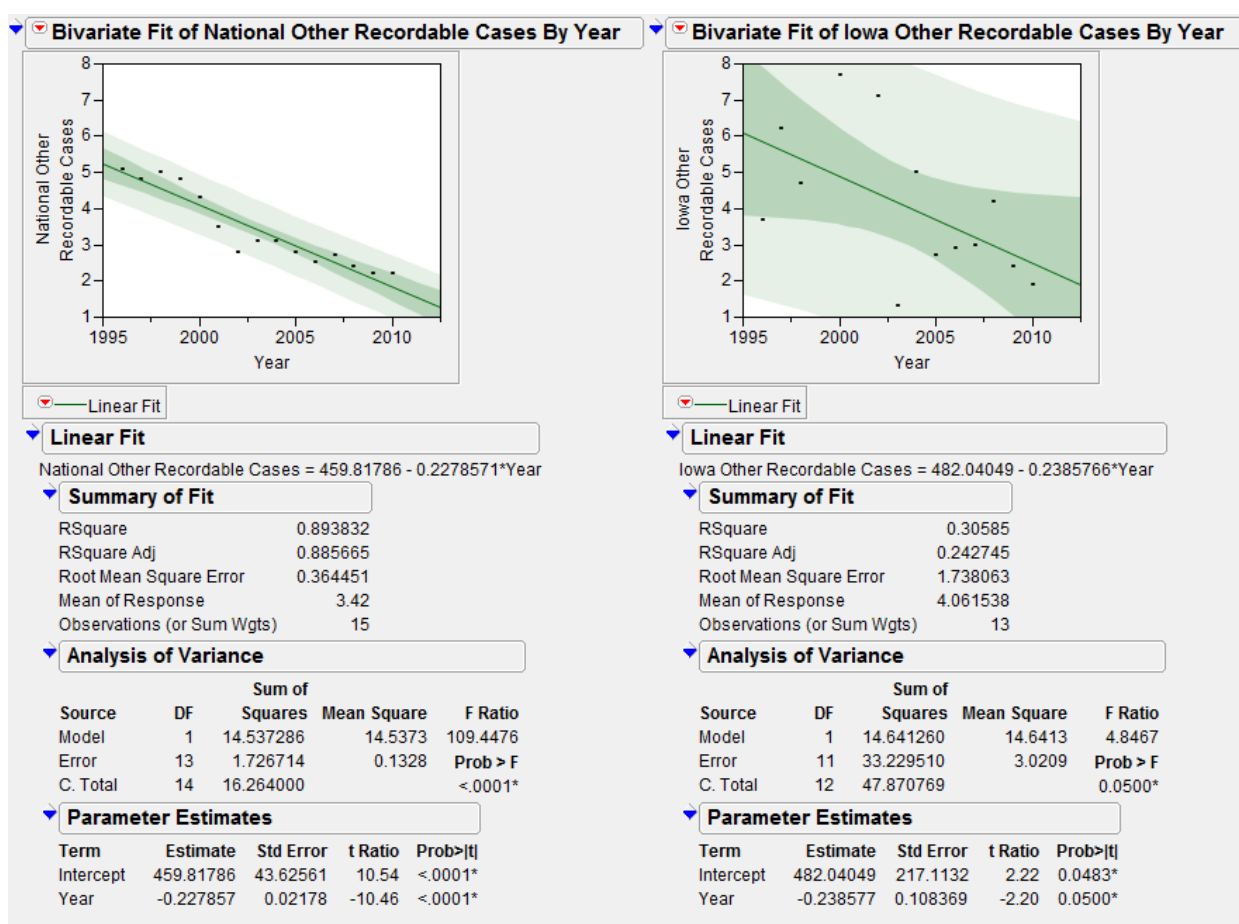


Figure 4.7 – Linear fit for other recordable cases (National and Iowa)

Figure 4.7 includes the JMP version 8 output of an Analysis of Variance test as well as a linear regression model for National and Iowa rates for “Other Recordable Cases”. When analyzing the National yearly rates, there is a clear downward trend with a very tight confidence interval. The coefficient of determination of the national data is high at 0.893 which means that the linear model of $[Recordable\ Case\ Rate = (459.82) - (0.228 * Year)]$ is

a very accurate and predictive model. Iowa yearly rates, in this case as well, are not as readily able to predict an accurate yearly rate for “Other Recordable Cases”. With an R-Square value of 0.306, the model is a poor predictor of “Other Recordable Cases”. This model also has a Standard Error that is five times as large as the national rate. Because of this, there is a large overlap that it cannot be said that the two models are significantly different.

4.6 - Summary of OSHA and Iowa OSHA data

When analyzing the predictive models using a linear regression in this chapter, it is found that it is extremely difficult to identify the source of the large variances within the Iowa OSHA data. There is a lot of statistical “noise” in the Iowa OSHA data that is likely attributed to having a smaller sample size than that of national levels. Iowa annual employment hours for Highway, Street, and Bridge in 2010 accounted for 4,900 of the 288,600 hours of the total annual employment which represents about two percent of all hours worked. Because of this small sample size it is likely that variance can be attributed to the type of work that is being performed each year. Iowa OSHA statistics are much more elastic because of this smaller sample size as well. A single incident will cause a much larger increase in the incident rate of an individual state more so than on the incident rate on a national level. In 2010, a single incident has 67 times more of an effect on the Iowa incident rate than a single incident that is accounted in national incident rate. This is due to the large difference in total annual employment.

National OSHA data on Highway, Street, and Bridge construction offers a very predictive model in all three categories that were explored. Since there were large sample sizes, it is more likely that a useful model will be provided in these cases. These models also have narrow confidence intervals which allow us to compare Iowa OSHA statistics to the national model. Since there are no useful measures when comparing Iowa data to other Iowa data because of the poor models, we can only compare individual Iowa values to the National OSHA model to show statistical similarities or differences.

4.7 - Comparing National and Iowa Statistics

A 95 percent confidence range can be calculated as such for models with a given Standard Error:

$$\text{Upper 95\% Limit} = (\text{Model National Rate}) + (\text{Standard Error}) * (1.96)$$

$$\text{Lower 95\% Limit} = (\text{Model National Rate}) - (\text{Standard Error}) * (1.96)$$

For Total Recordable Cases, the Standard Error is equal to 0.0197 which gives a 95 percent confidence interval of:

$$(\text{Model National Rate})(+/-)(0.0385)$$

Using this confidence interval, five out of thirteen years included in the sample for Total Recordable cases are considered statistically lower than the national incident rate whereas eight out of thirteen years are considered to be statistically higher than the national incident rate. There were zero years where the Iowa and National rates were considered to not be statistically different.

For Total Cases with Days Away From Work, Job Restriction, or Job Transfer, the Standard Error is equal to 0.0189 which gives a confidence interval of:

$$(\text{Model National Rate})(+/-)(0.0370)$$

Using this confidence interval, five out of thirteen years included in the sample for Total Recordable cases are considered statistically lower than the national incident rate whereas eight out of thirteen years are considered to be statistically higher than the national incident rate. There were zero years where the Iowa and National rates were considered to not be statistically different.

For Other Recordable cases, the Standard Error is equal to 0.0218 which gives a confidence interval of:

$$(Model\ National\ Rate)(+/-)(0.0427)$$

Using this confidence interval, four out of thirteen years included in the sample for Total Recordable cases are considered statistically lower than the national incident rate whereas nine out of thirteen years are considered to be statistically higher than the national incident rate. There were zero years where the Iowa and National rates were considered to not be statistically different.

4.8 - Iowa DOT Crash Database

The Iowa Department of Transportation maintains a crash data base that includes information about each type of vehicle crash that occurs in the state of Iowa. Within the data that is kept by the Iowa DOT, a large set of variables are used by the reporting officer to describe the conditions in which the incident occurred. Based on these variables, a query is performed to filter different types of conditions to explore the make-up of crashes within Iowa. The variables that were considered for our study are included in Appendix A and contain information regarding the following: the case number in which the incident was assigned, the vehicle configuration in the incident, and the work zone location in which the incident occurred. In this study the interactions between these variables are of particular interest because of how the work zone interacts with each area. After this is done an analysis of each work zone can be performed to see which areas are particularly dangerous or what zones need to be addressed.

The case number was important to identify so that a sample of the total incidents could then later be investigated further through the incident narratives. The vehicle configuration of each case was considered because it was important to find out what, if any, types of large construction vehicles are involved in incidents. The work zone location variable is especially important in this study as it pertains directly with how and at what locations construction operations are interfacing with the traveling public. The zones that were identified as work zone related are illustrated below in Figure 4.5. These zones are defined by the Iowa DOT and are used specifically in incident reports by the reporting public officer of each incident. These zones include:

- Zone 1 – Before the advanced warning sign
- Zone 2 – Between the advanced warning sign and lane shift
- Zone 3 – Within the lane shift
- Zone 4 – Within the work zone
- Zone 5 – Outside of the work zone

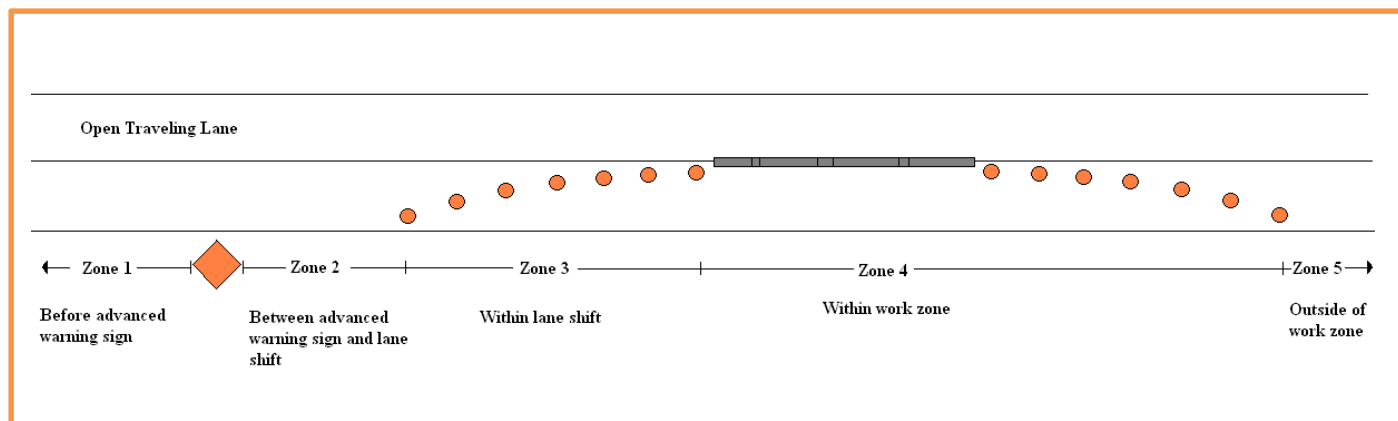


Figure 4.8 – Illustration of construction “Zones” as defined by the Iowa DOT

The work zone locations that were identified by the Technical Advisory Committee to be the most problematic were “Zone 3” and the egress from the work zone in “Zone 4.” It was cited that often it is extremely difficult for trucks and other heavy equipment to enter and exit a work zone and in turn were creating dangerous conditions for both the truck driver and the traveling public. Each major type of equipment that was identified is highlighted below. The query of the Iowa DOT database produced the following results included in Table 4.1:

Vehicle Type	Number of Incidents by Work Zone Location					Total
	1	2	3	4	5	
Passenger car	97	171	184	515	27	994
Four-tire light truck (pick-up/panel)	18	71	65	176	9	339
Van or mini-van	17	27	37	99	8	188
Sport utility vehicle	22	55	54	136	13	280
Single-unit truck (2-axle/6-tire)	3	7	5	26	-	41
Single-unit truck (≥ 3 axles)	-	4	4	19	1	28
Truck/trailer	-	3	6	6	1	16
Truck tractor (bobtail)	-	2	0	0	0	2
Tractor/semi-trailer	5	26	22	80	9	142
Tractor/doubles	-	1	1	4	1	7
Tractor/triples	-	-	-	-	-	0
Other heavy truck (cannot classify)	-	-	-	-	-	0
Motor home/recreational vehicle	3	1	2	2	-	8
Motorcycle	1	5	12	36	2	56
Moped/All-Terrain Vehicle	-	-	-	1	-	1
School bus (seats > 15)	-	1	-	-	1	2
Small school bus (seats 9-15)	-	-	-	-	-	0
Other bus (seats > 15)	1	-	3	8	-	12
Other small bus (seats 9-15)	1	-	-	1	-	2
Farm vehicle/equipment	-	1	1	1	-	3
Maintenance/construction vehicle	1	-	-	8	-	9
Train	-	-	-	-	-	0
Other (explain in narrative)	-	-	-	-	-	0
Not reported.	-	2	2	1	1	6
Unknown	-	-	-	-	-	0
Total	169	377	398	1119	73	2145
Total Construction Vehicle/Heavy Equipment	8	42	37	139	11	229

Table 4.1 – Crashes by vehicle type and work zone location

The table included produces information that pertains to each work zone, how many incidents are occurring in each zone, and also what types of vehicles are involved in these

incidents. Zone 4 has an overwhelming number of the incidents included in its category whereas Zones 2 and 3 each have a large portion of the incidents as well.

4.9 - Crash Narratives

It is difficult to determine the cause of many incidents only by the raw data that is included in each descriptive statistic in the Iowa DOT Crash Database. Because of this, a ten percent sample of the incident narratives was analyzed. The sample was taken from vehicle configurations that were considered to be “Heavy Equipment” or “Construction Vehicles” which are highlighted in Table 4.1. Also because Zones 2, 3, and 4 were identified as being the most problematic areas of a work zone when it comes to work zone mobility, samples were only taken from those three areas. An example of how each sample was taken is shown below in Table 4.2

	Number of Incidents by Work Zone Location		
	Zone 2	Zone 3	Zone 4
Single-unit truck (2-axle/6-tire)	7	5	26
Narrative Sample Taken	1	1	3

Table 4.2 – Table of example sample taken for crash narratives.

These crash narratives provide additional information that the reporting officer deemed necessary to include in the overall crash report. This includes any additional information about road conditions, direction of travel of any and all of the vehicles involved in the incident, and illustrative diagrams showing the types of road systems and relative distances. These conditions were then analyzed and categorized by either the major cause of the incident or the environmental factor that led to the incident. The major causes and environmental factors that were included in the categorization were merging traffic, rear end collision/following too close or too fast to stop in time, shoulder collision/shoulder drop off,

striking a utility pole, objects in road, loss of control, backing up, lane shift/narrow lane, and no included narrative. Included in Table 4.3 is a summary of the findings.

Major Cause/Environment	Number of Incidents	Percentage of Sample
Merging Traffic	6	22.2%
Rear end collision, Following too close or too fast to stop in time.	5	18.5%
Shoulder collision/drop off	4	14.8%
Struck utility pole	3	11.1%
Object in road	2	7.4%
Loss of Control	2	7.4%
Backing up	2	7.4%
Lane Shift/Narrow Lane	2	7.4%
No included narrative	1	3.7%
Total	27	100%

Table 4.3 – Summary of categorization of crash narratives

Looking at Table 4.3, we find that around 48 percent of the incidents in the sample involve merging traffic, rear end collisions/following too close, and lane shifts/narrow lanes. These types of incidents are generally related to “Zone 3” incidents which are within the lane shift of the work zone. This problem area was confirmed by the Technical Advisory Committee and was the basis of the ingress and egress survey included in this study.

Since the Iowa DOT crash data base did not specifically consider the egress from the construction site as its own zone, a survey was conducted to address these locations. This survey is addressed later in Chapter 4 and serves to address problems with not only the egress zone that is identified in Zone 5 in Figure 4.5, but also Zone 3.

4.10 - Personal Interviews

In this study, personal interviews served as a means to explore in depth topics with personnel who have a particular expertise. A total of four personal interviews were conducted in total including interviews of Roxanne Seward - Traffic Technician District 3 Iowa DOT, Jason Hankins – Project Manager for Cedar Valley Corporation, Jeff Koudelka – Vice President of Iowa Plains Signing, and Dave Webb – Plant 6 Operator for Central Iowa Ready Mix. These four people were identified as experts in each of their fields and offered a wide variety of experiences to traffic control, work zone safety and mobility, and internal traffic control.

Roxanne Seward - Traffic Technician District 3 Iowa DOT

As a traffic technician, Roxanne's experience includes implementation of Iowa DOT traffic control policies and procedures and is a member of the Tri-State Incident Management group that includes the states of Iowa, South Dakota, and Nebraska. The Tri-State Incident Management Group is a formation of several local Department of Transportation districts within the Siouxland area, which is located in Northwestern Iowa. The goal of the incident management group was to compile all relevant contacts within each district and to have response plans if incidents such as traffic accidents or required shut downs are anticipated to affect more than one state's municipality. All of these operations are performed as a part of the Siouxland Interstate Metropolitan Planning Council (SIMPCO). SIMPCO is a council of governments that serve the tri-state area of Iowa, Nebraska and South Dakota by using effective regional planning, promoting regional economic growth, and to be a model for other similar multi-municipality planning agencies. The Tri-State Incident Management

Group is considered to be a “best practice” within the Iowa DOT District 3 and Siouxland area.

Another best practice that was addressed in this interview was the reception of public concerns on traffic control and other construction related items. The Iowa DOT District 3 Office fully supports feedback from individuals and actively works to solve problems and concerns that emerge as a result of any work that is performed. All concerns that are brought to the District 3 office are documented and reviewed and are then forwarded and addressed by the proper personnel, whether it be a State Representative, City Council member, or even local law enforcement.

Jason Hankins – Project Manager for Cedar Valley Corporation

As a project manager for Cedar Valley Corporation, Jason addresses the daily work zone difficulties associated with highway construction. During the interview, these topics were of particular interest. The first topic covered was the process of changing a traffic control plan.

Any major change that is considered when making a change to traffic control plans must be formally submitted by the project manager to the Iowa DOT’s Resident Construction Engineer (RCE). Upon review, the RCE may approve of changes or make additional ones. Often times on major traffic switches these changes are approved ahead of time. Schematic diagrams and other paper submittals are often required of the contracting agency which leads to better documentation of the change. However can lead to added design time for the contractor if changes are not approved. Minor changes that effect small portions of a jobsite such as a single ingress point or cone set up often only needs the approval of an Iowa DOT inspector, not the RCE. These meetings are usually performed on the jobsite and do not need schematic plans or diagrams.

When designing changes the safety of all construction personnel are considered. All traffic control devices and traffic control plans must adhere to Manual Uniform Traffic Control Devices (MUTCD) plans and policies. This also means that any changes to traffic control plans must adhere to these standards unless an exemption is granted by the RCE.

Internal traffic control, however, is developed by the contracting agency on the highway project.

Input is closely considered from all contractors and subcontractors that are affected when developing internal traffic control plans. Any superintendents such as those who manage major portions of work are also asked for input. Regular meetings are held with Iowa DOT inspectors as well to address internal traffic control plans as well as items such as haul routes and planned closures. There is no standard design which addresses internal traffic control but final approval of internal traffic control plans by the RCE is required. Changes to internal traffic control plans are addressed much in the same manner that regular traffic control plans are in that minor changes are typically approved by the Iowa DOT inspector and major changes are approved by the RCE.

Along with the general process of changes to traffic and internal traffic control plans, a few challenges were also addressed. The aspect of the change process that was identified as being one of the most difficult was trying to make the case that proposed contractor changes to traffic control and internal traffic control plans are indeed safer, more convenient for the traveling public as well as construction operations, and offer a schedule benefit to the construction project. Contractors often push to limit the amount of time they are in one area to help limit the total exposure time of the construction time to the traveling public. The more schedule based projects with higher flexibility in closures offer the best situation for contractor operations. The contractor often feels it is best for safety and exposure to the public to have one mobilization of construction operations into an area and one demobilization from the jobsite once work is completed. It is rarely in the interest of the contractor to perform work in smaller segments.

To help reduce exposure to the traveling public it is the notion that contractors prefer to work on larger projects. This is due to the economies of scale that provide for higher productivity and reduce unit prices when performing work. Safety is believed to be improved because of this higher productivity because it reduces the overall time that is spent on construction per mile, thus limiting the total exposure to the public of hazards that are associated with highway construction.

Jeff Koudelka – Vice President of Iowa Plains Signing

Iowa Plains Signing is a traffic control contractor/subcontractor that can provide nearly every traffic control device or service desired for a highway or urban construction project. The interview conducted with Jeff worked to identify difficulties and best practices associated with Manual on Uniform Traffic Control Devices (MUTCD) plans and specifications.

MUTCD plans and specifications are used in highway construction projects to standardize traffic control and interactions between the traveling public and construction equipment and personnel. These plans and specifications explicitly depict items such as minimum and maximum distances on advanced warning signs, types of jobsite barrier to use, and typical ingress and egress distances. An example of a standard traffic control plan can be found in Appendix D.

The primary concern that was expressed by Jeff with relation to construction operations is the ability to attract driver attention and drivers' abilities to identify and respect the work zone. He feels driver distraction causes many more incidents than any failure of the construction contractor to adhere to safety standards. To help curb this problem of drivers not paying attention to changing roadway conditions, strobe-type warning lights have been installed all vehicles to help warn the traveling public. This is not a DOT safety standard; rather it is a best practice implement by Iowa Plains Signing that goes above and beyond the typical standard.

Another best practice that was identified within the interview was that there are different strategies for getting drivers' attention on highway projects. These strategies coincide with two types of highway construction projects, the first being two-way two lane construction and interstate and divided highway projects. It was cited that it is detrimental to project safety to have excessive vehicles and attention grabbing devices around the jobsite because it distracts drivers from paying attention to other drivers and the actual construction itself. With divided highway and interstate construction, however, it is detrimental to project

safety to have fewer vehicles and attention grabbing devices and it is encouraged to use optional allowed devices.

Another point of emphasis that was discussed in the interview was the clarity of diagrams in the traffic control diagram and the inability to go above and beyond the standards shown. In several of the diagrams (one for example is TC-431) include graphics of vehicles that are to be used in the fleet but near them is an indicator that the piece of equipment is optional. It was reasoned that if it is included in the road standard, the piece of equipment should not be optional and should always be included. Iowa Plains Signing never allows a piece of equipment or sign to be optional in an operation if it is shown as so on the Iowa DOT Traffic Control Standard. Also, often times the vehicles that are depicted in the diagrams do not accurately show the realistic footprint of a piece of equipment. For example a rumble strip grinder may be shown to be working outside of the traveling lane on the diagram, but in reality the grinder may be sitting a few feet into the lane or even entirely in the lane of travel.

The second major category of concern is that since Iowa DOT standards are very specific in how they should be implemented (number of signs, number of trucks, ect.). Contractors feel that they cannot go above and beyond the standards without being liable for damages outside of their work zone. Standards often constrict the contractor to perform to a standard that does not allow for additional safety measures. Past litigation that Iowa Plains Signing has been faced with for not adhering to the Traffic Control Standards had forced the dilemma of either risking liability because of extra safety measures, or potentially risking injury or property damage. They are not willing to provide additional signage and other safety equipment.

The last main topic of discussion was the lack of willingness to accept new safety products and implement them in DOT Standards. One item that was specifically identified were temporary rumble strips as seen in Appendix C. These have the ability to grab the attention of drivers and alert them to the potential hazardous situations ahead and can be included in operations which require temporary set up in a specific area. Some innovative items, though, have been adopted in the Iowa DOT standards as recently as 2011. The latest

equipment being used in traffic control are temporary automated signal lights, which replace standard flagging controls. This allows for two fewer laborers to be outside of a vehicle and exposed to moving traffic.

Dave Webb – Plant 6 Operator for Central Iowa Ready Mix

Dave is a ready mix plant operator and has 30 years of experience in the highway construction business and in particular has a wide variety of equipment operator and driver experience. He is one of the individuals credited with the development of Central Iowa Ready Mix's comprehensive driver safety and training program. A mentor/mentee relationship between drivers and operators is the backbone of the training program. Six major categories of safety and training are included in the program and include the following:

- 1.) A mentoring program where a younger, inexperienced driver is paired with an older, more experienced driver.
- 2.) A driver recognition safety course which helps train drivers on identifying drivers near the vehicle they are operating.
- 3.) A look-ahead program in which drivers are trained to actively seek potential problems on the roadways.
- 4.) Escape route training where drivers are trained to have an alternate plan of action if differing conditions are experienced than that of previous communications.
- 5.) Training on hazard identification within jobsites.
- 6.) Hand signal training in which drivers learn standard hand signals that are given by spotters.

These training programs are coupled with practices that include commentary driving, establishing communication lines, and job site drive-throughs. Commentary driving is a concept that was developed to allow drivers to actively assess job site conditions with the help of a mentor in the cab with them. The inexperienced driver gets to operate the vehicle with the help of an experienced driver and is encouraged to actively seek out potential problems

and communicate them with the mentor. This helps establish consistent behavior in active hazard identification.

Establishing communication lines have contributed vastly to the feedback loop that equipment operators and dispatch share. Since drivers are encouraged to actively seek out hazards and report back, the dangerous effects of differing conditions are mitigated. Drivers are trained to be “100 percent sure, or don’t go”, meaning that if the driver is not completely confident about the safety of the desired route that is to be taken. Plant operators and dispatch are then tasked with communicating information to all drivers including those who are en-route to the specified jobsite. Driving and route descriptions on dispatch tickets are changed and these new instructions are reviewed. If a change is major, the next step of the process is completed, the jobsite drive through.

A job site drive-through is a major part of the safety program in that it allows managers to directly show operators and drivers the haul routes and potential hazards. These drive-throughs are generally performed during all major changes in haul routes and jobsite traffic routes. By using a large passenger van to accommodate many drivers and operators, discussions can be held between the drivers themselves and in effect another form of commentary driving is established.

4.11 - Ingress and Egress Survey

A survey was performed as a result of the Technical Advisory Committee identifying that ingress and egress of equipment into and from jobsites was among the most dangerous activities associated with highway construction work zones. Public awareness as well as items such as congested jobsites and short acceleration and stopping distances were cited as some of the most critical problems that drivers and operators face. It was also determined by the TAC that there were two distinct types of highway construction work zones. The first type of work zone identified was considered to be a “closed” work zone. This meant that the work zone is protected in some manner, usually by a concrete barrier rail which provides additional protection from the traveling public within the jobsite. The second type of work

zone identified was an “open” work zone. This type of work zone is generally used for short term lane closures and does not use any physical barriers to protect the workers or construction equipment, only cones are used to mark lane closures.

Each respondent was asked to identify three best practices for both “closed” and “open” work zones. The population identified included Iowa DOT officials, officials from adjacent states’ Departments of Transportation, as well as contractors. A total of 19 responses were recorded for each type of work zone and the results are categorized and summarized below.

	"Closed" Work Zone	"Open" Work Zone
Upgrade/Additional Equipment, Markings	20	18
Additional distance for ingress and egress	6	6
Using correct, clean, and undamaged traffic control devices	6	3
Use alternative ingress and egress points	4	4
Better protection, communication with, and training of workers	4	3
Have Public Officer on Site	2	1
Use of Pilot Car	0	2
Other	10	12
Did not respond	5	8

Table 4.4 – Summary of categorization of Ingress and Egress Survey for “Closed” and “Open” work zones.

4.12 - Pilot Project

The pilot project that was used in this project was the Segment 1 update for Interstate 29 in Sioux City, Iowa. The Segment 1 portion of this project begins south of 8th Street in Sargent Bluff and extends north towards the Missouri River. Segment 1 is a part of a three segment interstate highway system improvement. The ultimate goals of the project are to improve safety, improve traffic operations, provide for better driver expectancy, and improve future roadway infrastructure conditions. (Iowa DOT, 2011). The Segment 1 improvement project includes expanding both northbound and southbound lanes from a four lane system to

a six lane system. Despite its adjacency to the Missouri River, a categorical exclusion was approved environmental constraints within the Segment 1 area. This meant that the cumulative environmental effects of the project would not be significant.

The major difficulties that were faced in this project were a combination of existing rail transport lines as well as geographical landscape constraints. On the eastern side running parallel with Segment 1, there is both an existing bike path as well as the Missouri River. Within this segment, sections of Interstate 29 lie within fifteen yards of the river bank. Equally close along the western side of Segment 1, lies an existing railway that is still in use. Another major difficulty in addition to the physical constraints is the inability for complete closure of the highway. The accumulation of these conditions led to a very difficult project to safely complete. Since travel lanes could not be completely restricted, it was proposed by the Iowa DOT to perform construction at night and allow a single lane closure, keeping one lane open in each direction. However the contractor that was awarded the project developed a proposal plan that would allow them to work during the day.

The major components of the proposal included the following:

- 1.) Narrow the work zone where the additional lanes were to be constructed.
- 2.) Shift traveling lanes for both north and southbound lanes outward from the centerline of the highway so both travel lanes could remain open.
- 3.) Perform work during the day so it can be performed at their highest production rates to minimize the construction schedule and in turn, minimize exposure of the work zone to the traveling public.

The overall goal of the new traffic control and work zone plan was to allow construction operations to be performed during the day at peak production, allow minimal disruption to traffic flow, and limit the duration of the total construction time. This proposal was approved by the District 3 Resident Construction Engineer and construction proceeded per the contractor's proposal. Adequate planning and preparation by the contractor allowed for the internal traffic control plan, as well as the public traffic control plan were successfully adapted per the contractor's request. Because of the newly implemented traffic control and

work zone control plan, the project was able to be completed in a productive manner that helped to reduce the total exposure time of the construction project to the traveling public.

Chapter 5 – Conclusions

The analysis of both quantitative and qualitative data in this study should be used in combination to make inferences about what safety measures and safety programs should be implemented or how existing programs can be modified. The models in the following section are designed to be used as tools to supplement existing safety procedures and are not to be used as a complete program overhaul. The use of integrated risk modeling in this section are designed in much the same way but are to address which parties should have input and at what stage of a construction project their input is required.

5.1 - OSHA and Iowa OSHA

Based on the data provided by OSHA and Iowa OSHA, incident rates were compared using a linear regression model and an analysis of variance was performed for both sets of data. Since the category “Highway, Street, and Bridge construction” has a relatively small sample size for the total annual employment for Iowa, a lot of statistical variation is seen in Iowa Data. Since, however, a much larger population size is used for national incident rates we can compare individual yearly statistics for Iowa to the linear model developed in Chapter 4.

Based on the findings in Chapter 4, since data has been collected as “Highway, Street, and Bridge Construction,” Iowa has, more than half of the time, had a higher incident rate in every major statistical category. These findings indicate that, due to many factors, Iowa is often a statistically more dangerous state to work in highway construction than the national average. This could be due to many factors such as extreme weather conditions in both summer and winter, types of construction projects performed, or types of safety programs that are implemented. The exact factors causing the higher rate are not able to be identified in this study alone and are likely a source of future research.

One positive that can be identified is that models for both Iowa and National incident rates are downward sloping and that Iowa models, however weak they are, are still trending downward. The model for “Total Recordable Cases” in Chapter 4 offers the best evidence that overall incident rates for Iowa are improving from year to year. The linear models in Chapter 4 also display similar slopes in the downward trends for each analysis that was performed.

5.2 - Iowa DOT Crash Data Base

The Iowa DOT Crash Database provided a way to categorize incidents that are considered by a reporting officer to be work zone related. Table 4.1 provides a summary of the crash data in Chapter 4. The zones considered within the table included the following categories:

Zone 1 – Before the advanced warning sign

Zone 2 – Between the advanced warning sign and lane shift

Zone 3 – Within the lane shift

Zone 4 – Within the work zone

Zone 5 – Outside of the work zone

It was anticipated by the Technical Advisory Committee that the lane shift category, or Zone 3, was the cause for the most incidents and was the most problematic area for heavy equipment. However in the data base query we found that there was not much difference between the number of incidents associated with Zones 2 and 3. Zone 2 had forty-two incidents where as Zone 3 had thirty-seven incidents. The overwhelming majority of incidents that are occurring that include heavy equipment is Zone 4, which accounts for 139 of the 229 total incidents. Zones 1 and 5 accounted for the fewest incidents among the group but still account for 19 of the 229 total incidents.

The discrepancy between the experiences of the expert panel and the data provided by the Iowa DOT crash data base serve as conflicting information in this study. In this case, further examination must be considered when analyzing this data. The discrepancy found could be a source of many different problems. One possible contributing factor to the conflicting evidence is that reporting officers may not be consistently or correctly identifying the zones in which a work zone related incident is occurring. Training procedures on filling this section of the incident form may not be consistent between jurisdictions. Another source of variance from the reporting officer may be that since each highway construction project is unique, it would be difficult to identify comparable zones for each highway project.

Another likely source of the overwhelming majority of the incidents that occur in Zone 4 is because of the amount of exposure that the traveling public receives. In a particularly long work zone, the relative sizes of Zones 3 and 4 may be drastically different. Zone 4 may not be any more dangerous than Zone 3 but simply because Zone 4 accounts for a higher percentage of the overall jobsite length, it will have more incidents associated with it. This was identified as the most likely source of the discrepancy between expert panel experience and statistical data.

5.3 - Incident Reports

Due to the conflicting evidence presented by the Technical Advisory Committee and the Iowa DOT Crash Database, a ten percent sample of individual incident narratives was analyzed to supplement previous evidence. Within these individual reports included detailed information about each incident.

Within these narratives it became clear that the zone that each incident occurred was not the only major cause that leads to each incident. From the narratives it became clear that the types of incidents that were occurring may be just as critical as the location in which they are happening. For example, merging traffic in Zone 3 may cause traffic well beyond Zone 3 and into Zone 2 to form a large queue. This lineup of cars then could potentially lead to an incident that occurs in Zone 2 but in effect is an incident caused by activity in Zone 3. This is not accounted for in the classification of the location of the incident that is work zone related.

Much of the data in Table 4.3 alluded to many of the incidents being caused by a typical Zone 3 activity.

The most relevant information that would need to appear in future incident reports is the location of the cause of the incident. This would allow for the analysis for the types of incidents to coincide directly with the location of the cause of the incident rather than the location of the incident.

5.4 - Ingress and Egress Survey

Through the assessment of the ingress and egress survey several conclusions can be made about addressing concerns on ingress and egress points on highway construction sites. Since all but one respondent was a Department of Transportation Official from either Iowa or a surrounding state, inferences can only be made about the owner's view of ingress and egress safety.

For the "Closed" work zone, by combining the groups "Upgrade/additional equipment, markings" and "Using correct, clean, and undamaged traffic control devices," nearly half of the responses address use of some type of equipment. Owners, especially inspectors for owners, reported that improper use of traffic control equipment can be a major contributor that causes confusion for truck drivers, equipment operators, and the traveling public alike. Additional equipment and upgrading equipment often comes in the form of signage, arrow boards, message boards, and any other additional equipment that a contractor can provide to either protect its jobsite or to communicate with the traveling public. This assessment is supported by the insights provided by the traffic control contractor in the personal interviews. In their previous experience the more devices that are provided to grab the attention of drivers in either a divided highway or interstate highway construction project, the more aware that drivers will be and in turn, the safer the project will be.

The second major category of responses addressed problems with ingress and egress by means of either extending distances for ingress and egress so that drivers and operators

are able to accelerate or decelerate, or providing an alternate route that is less congested by the traveling public. If either of these techniques are able to be implemented in a particular project, they would certainly improve the interactions that truck drivers have with the traveling public. Not only can the safety of ingress and egress be improved by using alternate routes, items such as alternative delivery methods can be assessed on a project specific basis to help minimize interactions and incidents involving the traveling public.

Many of the individual responses were very similar to addressing ingress and egress safety improvement with one exception. Many of the respondents provided many more unique answers for the “Open” work zone. Individual answers did not agree as strongly on the “Open” work zone improvements when compared to the “Closed” work zones. The most likely explanation of the variance between the two types of work zones is the individual variance of the “Closed” work zone when compared to an “Open” work zone. Typical “Closed” work zones are often set up in a very similar manner from project to project. The same types of channeling devices, barriers, and other traffic control devices are used in every “Closed” work zone and standard traffic control plans are easier to implement. However with an “Open” work zone, many more unique situations that require an adapted traffic control plan are required.

5.5 - Developing the Jobsite Communication Model

Through the solicitation of personal interviews and the insight provided by the technical advisory committee, a “Lines of Communication Model” was developed. More specifically, jobsite communication models are a concept derived in this study from the combination of the interview with the ready mix plant operator and the common theme of effective communication that was cited in almost qualitative data collection interaction. Included in the model are the roles of DOT officials, project managers, project foreman, plant operators, equipment dispatchers, and equipment operators. Solid lines represent primary lines of communication and dashed lines represent secondary lines of communication.

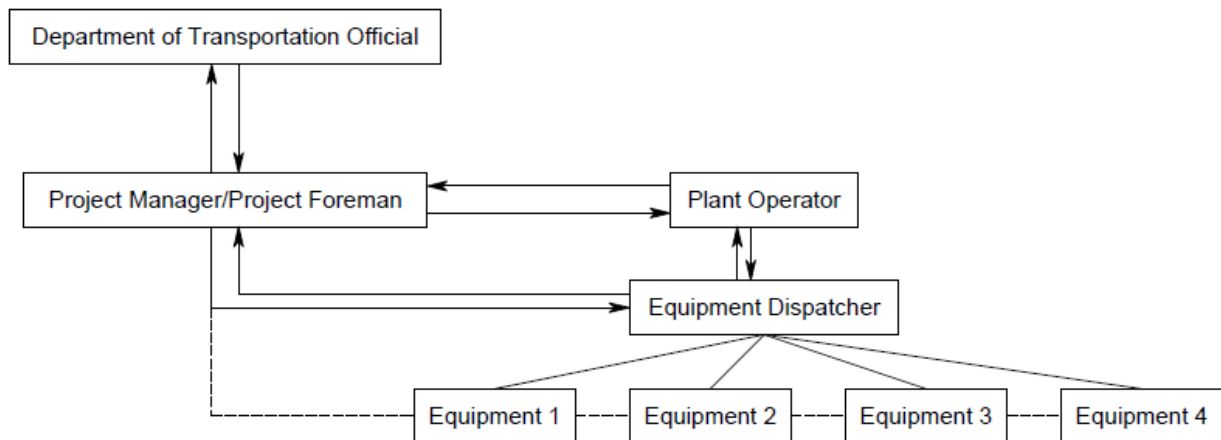


Figure 5.1 - Example jobsite communication model

In all highway construction projects it is essential that lines of communication are thoroughly established and open. Conflicts often arise from parties not knowing who to contact, or parties not forwarding relevant information to the proper people. Because of the volatility and ever changing conditions of a jobsite it must be noted that each model that is developed for a project must be flexible and adaptable to changes. It is the responsibility of Project Managers and Project Foremen to receive input from all relevant parties included in the operation. Ideally models would be developed with specific names of personnel, their contact information, and a secondary contact in case the primary contact is not available.

Communicating Major Changes

For example, if there are major changes to ingress and egress points, a project manager must consult with the Resident Construction Engineer (RCE) within the district. After any major changes or modifications are approved by the RCE, this information must be clearly and concisely passed to both plant operators and equipment dispatchers. Once this has been completed the dispatcher is responsible for communicating these changes to the equipment operators. This can be done in a number of ways. A jobsite “drive through” may be performed using a large passenger van to show operators the new haul route or roadway within the jobsite. If the changes were known ahead of time by the equipment operators or the changes are minor, radio communication between dispatch and operators may suffice.

However, if a more hands on approach is taken with regards to communication, it is much more likely that relevant information will be passed on.

Communicating Differing Conditions

Since a jobsite is dynamic in so many ways, not only must there be a line of communication from a management level to an operator or laborer level, laborers and operators must be able to communicate changes in jobsite conditions up the model to management personnel. Along with communicating to their own dispatch and plant operator, they must also be able to communicate to the project manager or project foreman. An active approach by any driver or operator must be taken to ensure that any differing condition be communicated to other drivers, as well as management personnel. An example model is provided in Figure 6.2

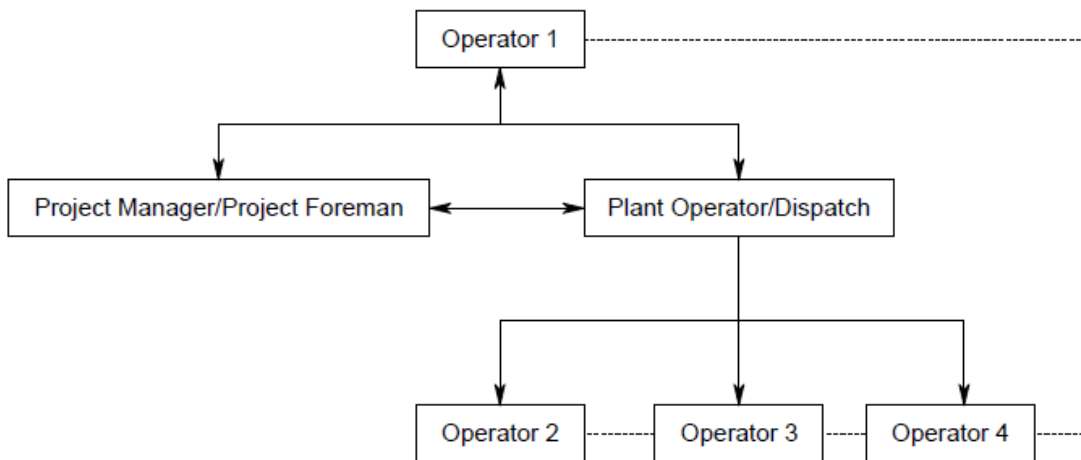


Figure 5.2 – Differing conditions communication model

Coordination of Equipment Deliveries

Often a communication model will need to be adjusted or modified. If a new equipment delivery is to arrive on site a communication model that is developed may resemble the model in Figure 6.3. If multiple points of dispatch need to be considered they

will often have to work closely to coordinate the delivery, especially in congested work zones. To ensure mobility of both the additional equipment and the existing operations it is likely that many more secondary lines of communication must be established.

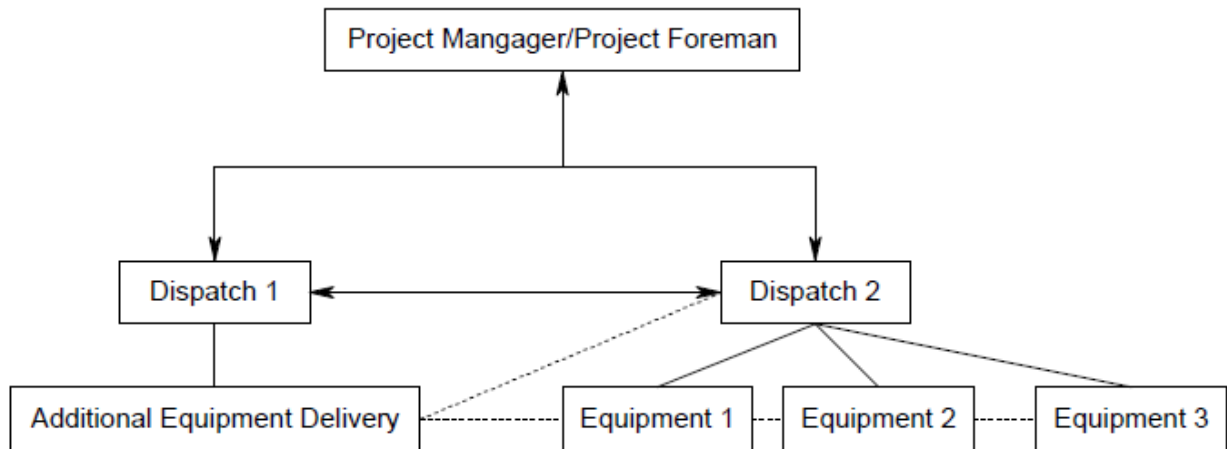


Figure 5.3 - Communication model for major equipment delivery

5.6 - Summary of Conclusions

- 1.) OSHA and Iowa OSHA data should be used as a basis to compare safety on a state wide and on a national level. Metrics are difficult to provide within individual states, however, individual states should compare incident rates to national averages and push to keep the trend of decreasing incident rates. Iowa, in the past 15 years, has not proven to have lower incident rates than the national average and more often than not have reported statistically higher incident rates than the national average.
- 2.) The Iowa DOT Crash Data base has been an effective tool in analyzing incidents that are work zone related. At this point in time, cases in “Zone 4” or cases that are work zone related that occur within the work zone represent by far the highest percentage of incidents as far as location is concerned. Although this can be for a number of reasons, it represents the most problematic area with regards to how contractors interact with the traveling public.
- 3.) The methods in which reporting officers identify the location of an incident within the Iowa DOT’s defined work zones (Zone 1 through Zone 5) should be reviewed to

- ensure consistency in reporting. Also the manner in which crash narratives are filled out within each incident is essential to identifying the major causes of each incident. Consistency is of the upmost importance when trying to normalize this data.
- 4.) Ingress and egress zones on construction jobsites, as expressed by the Technical Advisory Committee and during personal interviews, represent the most challenging areas to address work zone safety and mobility. Although these zones do not represent the highest frequency of incidents, it was consistently cited by contractors, truck drivers, and Iowa DOT personnel as the most difficult areas to control throughout this study. Additional measures in preconstruction planning could provide additional work zone safety and serve as a time to discuss alternate methods of ingress and egress. This can be done for not only vehicles, but material deliveries as well.
 - 5.) Personal interviews with persons of various technical backgrounds are essential to formulate the basis of highway construction research. Since highway construction is such a dynamic industry that is subjected to so many unique project-level difficulties, it is difficult to normalize data. A mixed-methods approach where qualitative assessments are used are valuable to confirm conclusions that are found. These same methods should also be used to identify and address discrepancies between common conceptions of highway construction safety and conclusions that statistical data provide.
 - 6.) Effective jobsite communication was a theme that was encountered in almost every stage of this research project. More specifically the individual interactions between plant operators, dispatch, foremen, and drivers are the most crucial interactions that pertain to on the job work zone safety and internal traffic control. To support those interactions effective training programs and project specific communication models should be developed so that roles and responsibilities of each party are clear.
 - 7.) Per the Pilot Project, contractors have the ability to make major changes to internal traffic control plans as well as address how work zone vehicles interact with the traveling public. Alternative plans, although not always implemented, should always be considered if a potential for improvement in safety, productivity, or cost

effectiveness can be realized. Construction means and methods should be analyzed comparatively with the ability of contractors as well as DOT officials to be flexible in implementing traffic control plans.

5.7 - Research Limitations

Within any project, research limitations must be addressed in order to give clear context to its findings. Each aspect of research in highway construction presents challenges that often cannot be overcome by one study. Highway construction is particularly difficult in that no two projects are the same. The conditions of each highway work zone present its own set of problems and challenges which often makes data difficult to baseline.

Iowa and National OSHA Statistics

The data population included in these sets include years 1996 through 2010. In most years, the statistic that is relevant to highway construction work zones is included in the “Highway, Street, and Bridge Construction” category. Any year that was not specifically categorized this way was not included in this study because they did not include all of the data necessary to normalize the data. Years that were not included in either the statistical models in Chapter 4 are 1999 and 2001. Data for these years were only not included for Iowa but was considered for national rates.

As it is conveyed in Chapter 4, the data analysis performed on the Iowa OSHA statistics revealed that a suitable predictive model could not be developed because of the extremely large variances within the data. This makes it difficult to compare data within the Iowa statistics other than to compare it to a simple average. However, if it is assumed that incident rates should be decreasing every year and not just below average, then a comparison to a statistical model must be performed. A statistical model for incident rates on a national level was able to be developed so this may lend as a comparative tool for incident rates in Iowa.

Iowa Department of Transportation Crash Data Base

The Iowa Department of Transportation keeps a data base of all incidents involving motor vehicle collisions or accidents in Iowa from year to year. Each incident is covered by a reporting officer and an incident report is filled out describing all of the major variables included in the incident. An example of an incident report can be found in Appendix B. Within this report include variables such as time of the incident, the types of vehicles involved, age of drivers, and whether or not the incident was work zone related. One variable that was particularly relevant to this study that is included in the Iowa DOT Database query is if the incident was work zone related. This statistic, however, was not kept until 2008. This limits our population sample to include data from 2008 to 2011.

One difficulty associated with collecting this data is that many of the variables included in the report depend on the discretion of the reporting officer. Each officer is trained to fill out these reports but many incidents are open to interpretation and feedback about the incident from the drivers themselves. Although the incident forms themselves are very standardized, there are still areas that are open to inconsistencies. Another item that must be noted with each incident is that the individual report includes all vehicles involved in the incident. This means that each incident likely has more than one driver and vehicle involved.

One of the inconsistencies found within the incident reports is the location within the work zone that a “work zone related” incident occurred. Sometimes it is unclear when comparing the type of incident that occurred to the location of the incident that is indicated within the incident report. For example, an incident that occurred because of merging traffic is often associated with a Zone 3, or within the lane shift, incident but may have been considered by the reporting officer to be a Zone 4 incident, or one that occurs within the work zone. Our sample of incident reports covers around 10 percent of the total incidents considered in the study which allowed more detailed information to be revealed about each incident. A larger sample may have led to more consistencies between the incident reports and the incident statistics.

Technical Advisory Committee

The Technical Advisory Committee was composed of two university professors, several Iowa Department of Transportation officials and employees, and several heavy and highway contractors. Although there is a diverse and a wide range of expertise, the suggestions and guidance of the Technical Advisory Committee is limited to their collective expertise. Although these limitations were mitigated by having several meetings and interactions, items such as pilot projects, jobsite tours, and any unique experiences may contribute in an unrepresentative manner to the study. With that statement, however, expertise from highway construction experts was essential to this project. Their experiences and insight lead to many of the research objectives that are addressed in this study.

Personal Interviews

The personal interviews performed in this study were completed in a combination of two different interview methods. The first is an Informal Conversation type interview and the second, a General Interview Guide. Questions were prepared before each interview was conducted but questions were not standardized. The intent of the study was not to interview several personnel over the same subject but to develop many different views of the same types of problems to depict a broad picture of the problems facing highway construction safety. For example, a traffic control technician was interviewed to explore difficulties when interfacing with the traveling public where as a Project Manager from a contracting agency was interviewed to explore difficulties that a contractor would face when interacting with DOT officials or when dealing with its own equipment. This interview style was performed deliberately to allow the flexibility in the answers provided by each individual to open up new ideas to address highway mobility and internal traffic control.

Many of the same challenges that were presented by the Technical Advisory Committee rose again during personal interviews. The insights provided by an individual person's interview are limited to their personal experiences and training. However, since the persons interviewed in this study are considered experts and a wide range of construction

personnel were interviewed, any individual bias is mitigated as well. Quantitative statistics as well as other qualitative research were also used to confirm individual experiences.

Pilot Project

A full safety implementation program was not performed as a part of this study. However, unique items regarding safety and jobsite mobility were addressed. The pilot project was not designed to implement new practices but served as a comparison to the “ideal” approach to work zone safety, mobility, and internal traffic control. Its basis was to identify either a typical or complex highway construction project and help identify unique processes and how those processes can be incorporated into a new safety program.

5.8 - Possible Future Research

Future research is often sprouted by the limitations or the findings of previous research. Work zone safety, mobility, and internal traffic control comprises a vast spectrum of topics of which involve wide varieties of personnel all of whom have an effect on its success. This project was framed around personal interviews with expert panel members and the analysis of general statistical data.

Normalizing of Iowa DOT Crash Data with relation to mileage would be an important statistical backing feature that would help eliminate some of the ambiguities presented by the findings in this study. Data for Zone 1 through Zone 5 of the work zone are difficult to compare since relative lengths are extremely different within each zone and are unique to each job site. Normalizing this data would include collecting data that indicates the length of each zone for either every highway construction project or a representative sample size of every highway construction project performed in a given year. Having this data would help to confirm or deny specific claims about which zone is the most dangerous and problematic for highway contractors.

An investigation in how reporting officers classify work zone related incidents would be valuable to perform as well because of the discrepancies discovered in this study. Inconsistencies in how each “Zone” is identified in individual incidents may be a major cause of some of the conflicting evidence in how work zone related incidents are reported. A second source of inconsistencies lies in the way reporting officers fill out incident narratives. In certain cases a very thorough narrative was discovered and the cause of the incident was very easy to identify and assign a classification. However, on the other end of the spectrum, a narrative was not provided for certain incidents at all which lead to the inability to classify the incident. Without consistent reporting from all jurisdictions, it is difficult to normalize data and thus it is difficult to statistically analyze data because of its limitations.

An extensive program level safety implementation project would likely be of interest to build on the findings of this project. For example a project related solely to ingress and egress on construction sites could provide research topics for future studies. From program

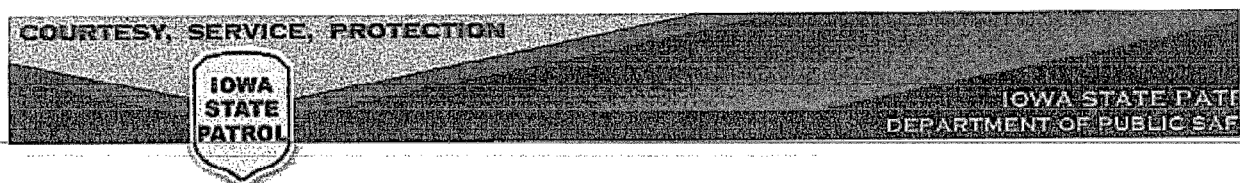
level implementation, a standardized mentoring program for drivers, operators, and laborers could also be explored.

Appendices

Appendix A - Variables used for Iowa DOT Crash Data Base query

Field Name	Field Description	Values	Values Descriptions	Field Type
CaseNumber	Case Number - Iowa DOT		4 digit year + number assigned by MVD (e.g., 2001002534)	Numeric: Integer
VConfig	Vehicle Configuration	1	Passenger car	Numeric: Integer
		2	Four-tire light truck (pick-up/panel)	
		3	Van or mini-van	
		4	Sport utility vehicle	
		5	Single-unit truck (2-axle/6-tire)	
		6	Single-unit truck (>= 3 axles)	
		7	Truck/trailer	
		8	Truck tractor (bobtail)	
		9	Tractor/semi-trailer	
		10	Tractor/doubles	
		11	Tractor/triples	
		12	Other heavy truck (cannot classify)	
		13	Motor home/recreational vehicle	
		14	Motorcycle	
		15	Moped/All-Terrain Vehicle	
		16	School bus (seats > 15)	
		17	Small school bus (seats 9-15)	
		18	Other bus (seats > 15)	
		19	Other small bus (seats 9-15)	
		20	Farm vehicle/equipment	
		21	Maintenance/construction vehicle	
		22	Train	
		23	Other (explain in narrative)	
		77	Not reported.	
		99	Unknown	
WZ_Related	Workzone Related?	1	Yes	Character
		2	No	
WZ_Loc	Location	1	Before work zone warning sign	Numeric: Integer
		2	Between advance warning sign and work area	
		3	Within transition area for lane shift	
		4	Within or adjacent to work activity	
		5	Between end of work area and End Work Zone sign	
		8	Other work zone area (explain in narrative)	
		9	Unknown	
		77	Not reported.	

Appendix B - Example incident report



Crash Information

L O C A T I O N	Date of Accident 5/11/2012	Time of Accident 12:10 PM	County Pottawattamie - 78	Accident occurred within corporate limits of (city)	Law Enforcement Case Number: [REDACTED]			
	Literal Description NB/EB INTERSTATE 0029 UNDERPASS OF INTERSTATE 0680 MEASURING 284 FEET SOUTH FROM INTERSTATE 0029 (MILEPOST 62)				Legal Intervention? No	Private Property No		
					X-Coordinate: 257377.8			
					Y-Coordinate 4582163.			
U N I T	Driver's Name - Last [REDACTED]		First [REDACTED]	Middle [REDACTED]	Suffix			
	City SOUTH SIOUX CITY		State NE - Nebraska, US		Zip 687760000			
	Driver's Age 22		Citation Charge Code 1 321.285		Citation Charge 1 FAILURE TO STOP WITHIN THE ASSURED CLEAR DISTANCE			
	Gender Female	State NE - Nebraska, US	Class	Endorsements None	Restrictions None	Citation Charge Code 2	Citation Charge 2	
	Alcohol Test Given? 1 - None		Drug Test Given? 1 - None		Citation Charge Code 3	Citation Charge 3		
	Seating Position 01 - Front: Left Side / Motorcycle Driver		Injury Status 5 - Uninjured	Occupant Protection 2 - Shoulder and lap belt used	Airbag Deployment 5 - Not deployed	Airbag Switch Status 3 - No ON/OFF switch present	Ejection 1 - Not ejected	Ejection Path Trapped 1 - Not trapped
	Transported to: NA				Transported by: NA			
	Insurance Co. Name							
	Year 2003	Make Ford - FORD	Model TAURUS	Style SES	Approximate Cost to Repair Replace 5000			
	Initial Travel Direction 1 - North	Vehicle Action 01 - Movement essentially straight	Speed Limit 65	Point of Initial Impact 01 - Front	Most Damaged Area 01 - Front	Extent of Damage 3 - Functional damage	Underride/Override 1 - None	
Total Occupants 01	Traffic Controls 01 - No controls present	Vehicle Config. 01 - Passenger car	Cargo Body Type 01 - Not applicable	Vehicle Defect 01 - None	Driver Condition 1 - Apparently normal	Vision Obscured 01 - Not obscured	Contributing Circumstances, Driver (up to 2)	
SEQUENCE OF EVENTS			First Event 06 - Evasive action (swerve, panic braking, etc.)	Second Event 21 - Vehicle in traffic	Third Event	Fourth Event	Most Harmful Event (by vehicle) 21 - Vehicle in traffic	
Emergency Vehicle Type 1 - Not applicable				Emergency Status 3 - Not Applicable				
Carrier Name		City		State		Zip		

Driver's Age 53					Citation Charge Code 1		Citation Charge 1		
Gender Male	State NE - Nebraska, US	Class	Endorsements None	Restrictions F - Outside Mirror	Citation Charge Code 2		Citation Charge 2		
Alcohol Test Given? 1 - None			Drug Test Given? 1 - None		Citation Charge Code 3		Citation Charge 3		
Seating Position 01 - Front: Left Side / Motorcycle Driver			Injury Status 5 - Uninjured		Occupant Protection 2 - Shoulder and lap belt used		Airbag Deployment 5 - Not deployed		
Airbag Switch Status 3 - No ON/OFF switch present			Ejection 1 - Not ejected		Ejection Path		Trapped 1 - Not trapped		
Transported to: NA					Transported by: NA				
Insurance Co. Name									
Year 2008	Make Ford - FORD		Model F150		Style PU		Approximate Cost to Repair Replace 2000		
Initial Travel Direction 1 - North	Vehicle Action 01 - Movement essentially straight	Speed Limit 70	Point of Initial Impact 05 - Rear	Most Damaged Area 05 - Rear	Extent of Damage 2 - Minor damage	Underride/Override 1 - None			
Total Occupants 01	Traffic Controls 01 - No controls present	Vehicle Config. 02 - Four-tire light truck (pick-up, panel)	Cargo Body Type 01 - Not applicable	Vehicle Defect 01 - None	Driver Condition 1 - Apparently normal	Vision Obscured 01 - Not obscured	Contributing Circumstances, Driver (up to 2)		
SEQUENCE OF EVENTS			First Event 21 - Vehicle in traffic	Second Event	Third Event	Fourth Event	Most Harmful Event (by vehicle) 21 - Vehicle in traffic		
Emergency Vehicle Type 1 - Not applicable					Emergency Status 3 - Not Applicable				
Carrier Name			City	State		Zip			
Number of Axles			Gross Vehicle Weight Rating		Placard #		Hazardous Materials Released		
ACCIDENT ENVIRONMENT				ROADWAY CHARACTERISTICS		WORKZONE RELATED?		SEQUENCE OF EVENTS	
Location of First Harmful Event 1 - On Roadway		Weather Conditions (up to two) 01 - Clear		Environment 1 - None apparent		Location		First Harmful Event of Cra (Use codes 11-42 only) 21 - Vehicle in tra	
Manner of Crash/Collision 3 - Rear-end				Roadway 01 - None apparent		Type			
Light Conditions 1 - Daylight		Surface Conditions 1		Type of Roadway Junction/Feature 01 - No special feature		Workers Present?			

D
I
A
G
R
A
M

0

I-29 NB



NARRATIVE

VEHICLE #2 WAS NB ON I 29. VEHICLE #1 ENTERED ON TO I-29 FROM 680 ON RAMP AND CONTIUNED NORTH O I-29. TRAFFIC IN FRONT OF VEHICLE #1 AND 2 BEGAN TO SLOW, VEHICLE #2 SLOWED FOR TRAFFIC, VEHICLE 1 TRIED TO SLOW BUT WAS UNABLE TO AVOID STRIKING VEHICLE #2 IN THE RIGHT REAR WITH VEHICLE #1'S LE FRONT. VEHICLE #1 DID HIT BRAKES AND ATTEMPTED TO SWERVE IN AN ATTEMPT TO MISS VEHICLE #2.

Officer MOORE	Badge No. 418	Time Officer Notified of Accident 12:32	Time Officer Arrived At Scene 13:04
Name of Agency P03	Date of Report 5/11/2012	Investigation made at scene? Yes	I.I. #

Appendix C – Examples of Innovative Technologies for future implementation.

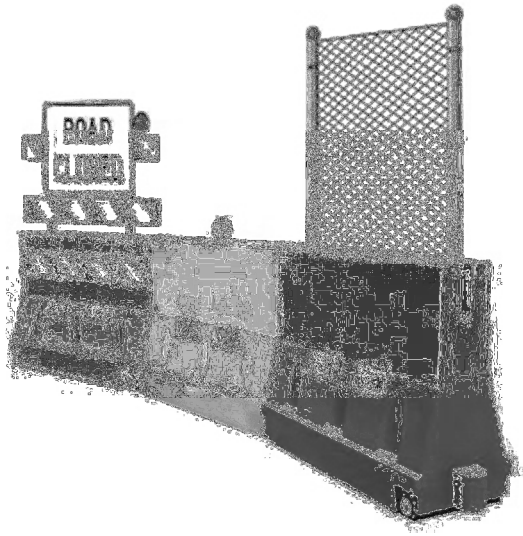
Figure C.1 - Temporary ruble strips



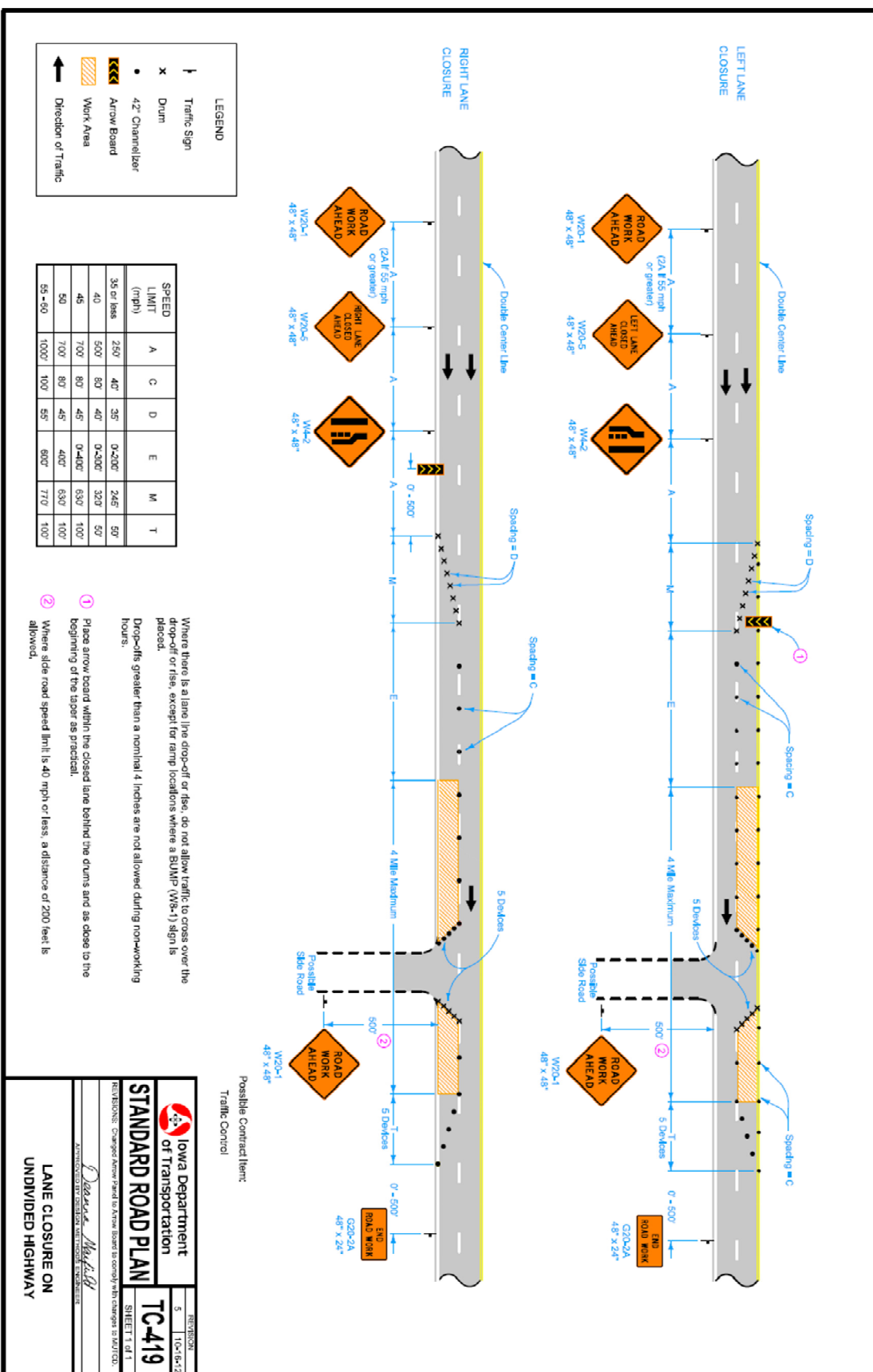
Figure C.2 - Temporary signal lighting

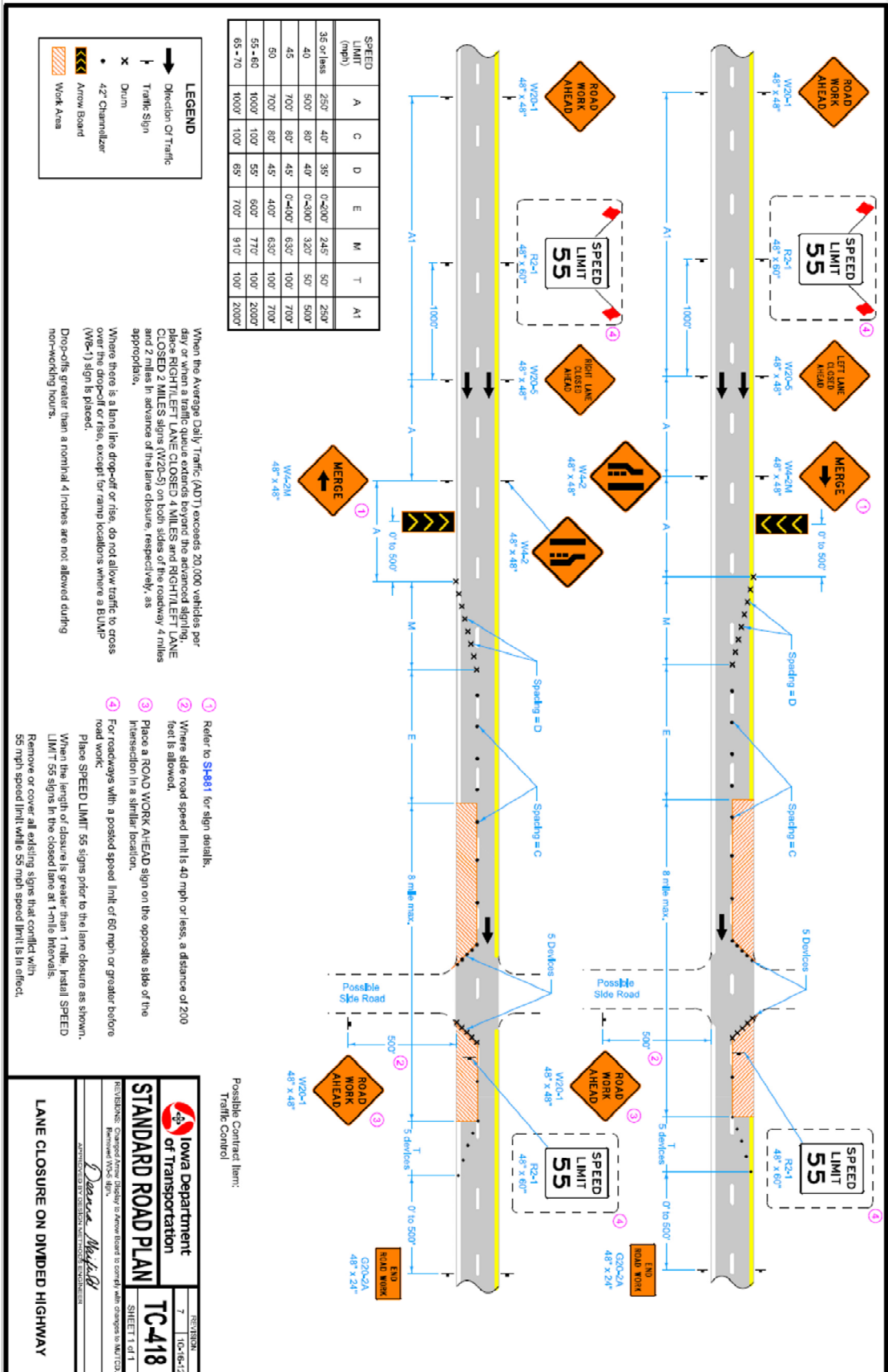


Figure C.3 – Water filled barrier system for interim term use



Appendix D – Example Traffic Control Plans





References

City of Baltimore (2011) “Baltimore, MD Usage of a Software-Based System to Coordinate Right-of-Way Activities and Reduce Impacts”

<http://ops.fhwa.dot.gov/wz/construction/crp/baltcasestudy/>. FHWA Workzone Safety and Mobility program. U.S. Department of Transportation Federal Highway Administration.

Envista (September 2009) “Allegheny County Selects Envista to Coordinate Public Works and Utility Projects” <http://www.envista.com/alleghenycounty>. Envista Corporation Beverly, MA

Graham, J. L. , Williams, C. L., Burch, R. (August 2005) “Internal Traffic Control Plans” Mid-Continent Transportation Research Symposium, Ames, Iowa.

Iowa State Patrol (2012) “Crash Information” Iowa Department of Public Safety

Iowa Department of Transportation (2012) “I-29 Improvement Project – Segment 2: Downtown Corridor” <http://www.iowadot.gov/i29/segment2.htm>. District 3, Iowa Department of Transportation, Sioux City, Iowa.

Laborers Health and Safety Fund of North America (December 2004) “Internal Traffic Control Plans Separate Trucks, Workers” Laborers’ Health and Safety Fund of North America, Washington D.C. Vol. 1, Num. 7.

New York City Department of Transportation (2011) “NYCityMap, DOTMap, and Other Online Information” http://www.nyc.gov/html/dot/streetworks/html/chapter_2/2_2.shtml. Street works Manual, Section 2.2

Occupational Safety and Health Administration (2012) “Forms for Recording Work-Related Injuries and Illnesses” U.S. Department of Labor.

Occupational Safety and Health Administration (January 2009) “Reflections on OSHA’s History” http://www.osha.gov/history/OSHA_HISTORY_3360s.pdf. U.S. Department of Labor. Washington DC.

Oregon Department of Transportation (2011) “Oregon Department of Transportation (ODOT) Three Levels of Transportation Management Plans TMPs” FHWA Workzone Safety and Mobility program. U.S. Department of Transportation Federal Highway Administration.

The Roadway Safety Alliance (2008) "Internal Traffic Control Plans" Published by the ARTBA Transportation Development foundation, U.S. Federal Highway Administration, and the Texas Transportation Institute.

Shane, J., Strong, K., Enz, D. (2009) "Construction project administration and management for mitigating work zone crashes and fatalities: An integrated risk management model" Institute of Transportation at Iowa State University. A report from the Midwest Transportation Consortium. Ames, IA.

Hankins, J (2011, October 20). Personal interview.

Koudelka, J (2011, February). Personal interview.

Seward, R. (2011, October 20), Personal interview.

Webb, D. (2012, February 15), Personal interview.