CONSTRUCTION MANAGEMENT AND TECHNOLOGY

Integrated Risk Management for Improving Internal Traffic Control, Work-Zone Safety, and Mobility during Major Construction

tech transfer summary

Internal traffic control design, along with how construction equipment and vehicles interact with the traveling public, have a significant effect on highway construction work-zone safety.

Problem Statement

Construction work zones are among the most dangerous places to work in any industry in the world. This is because many factors in construction, such as constant change in working environments and driver errors, contribute to a workplace with a higher number of accidents, injuries, property damage, and other losses when compared to other industries. Construction safety practices are essential to preventing loss on a job site and should be monitored during every project stage.

Background

Regulatory agencies such as the federal Occupational Safety and Health Administration (OSHA) have efforts to prevent unsafe work conditions, but regulatory agencies can only inspect a small percentage of job sites due to lack of resources. Therefore, safety agencies have expanded to the state level within the last 20 years. Local departments of transportation (DOTs) are also tasked with keeping statistical data to communicate safety trends within their own states and districts.

In addition to construction safety, work-zone mobility has a major effect on the safety of any highway construction job site and continues to be a topic of conversation for Iowa, Iowa DOT officials, utility companies, and contractors.

Highway construction sites differ from other construction sites in exposure to the traveling public, construction traffic, and heavy equipment. 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 individual level in the construction process, safety may be compromised.

To increase safety efforts, many perspectives must be considered to describe what is actually happening on job sites. 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.

Several types of quantitative as well as qualitative assessments were performed in this study. Common conclusions that were discovered between multiple assessments allows for stronger conclusions, especially when a quantitative analysis is able to support a qualitative claim by experts.

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RESEARCH PROJECT TITLE
Integrated Risk Management for Improving Internal Traffic Control, Work-Zone Safety, and Mobility during Major Construction

SPONSORS
Smart Work Zone Deployment Initiative
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The Construction Management and Technology (CMAT) Program is part of the Institute for Transportation (InTrans) at Iowa State University. The mission of CMAT is to improve the efficiency and cost-effectiveness of planning, designing, constructing, and operating transportation facilities through innovative construction processes and technologies.

SWZDI Smart Work Zone Deployment Initiative

IOWA STATE UNIVERSITY
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Work-zone safety, mobility, and internal traffic control are addressed by nearly every state DOT and many policies are available for review in the Federal Highway Administration (FHWA) databases. Even with this accumulation of significant information, highway construction is still one of the most dangerous industries in the US.

Research Objectives

The objective of this research was to investigate the application of integrated risk modeling to internal traffic control and contractor operations in construction work zones. The ultimate goal is to reduce frequency and intensity of loss events related to equipment movement and contractor operations in and around construction work zones.

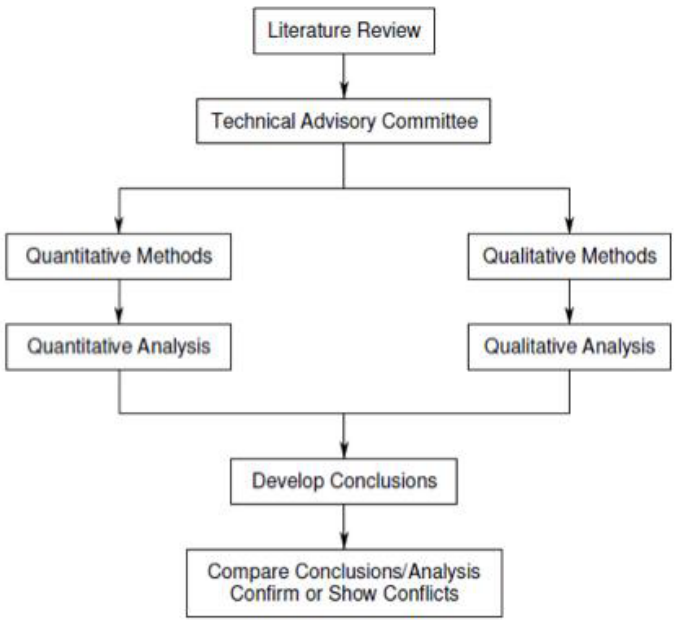
Research Methodology

A mixed-methods approach was chosen given 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.

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 quantitative research methods in this study included OSHA and Iowa OSHA statistics and analysis along with Iowa DOT crash database queries and analysis.

Qualitative research methods included the analysis of crash narratives, personal interviews with a range of construction personnel, an ingress and egress in construction work zones survey, and a work zone pilot project.



Research method diagram

Literature Review

The literature review revealed many different ways to mitigate 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 and are detailed in the final report.

Qualitative Assessments

To form a platform to conduct research on internal traffic control, work-zone safety, and mobility, a technical advisory committee (TAC) was formed. The TAC members are considered experts in highway construction and maintenance operations, represent various levels of management, and include local district managers and engineers.

Quantitative Assessments

Human factors, in certain instances, can be measured and looked at quantitatively. The Iowa DOT maintains a crash database in which reporting officers from each jurisdiction submit incident forms for crashes. 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, whether the incident was work-zone related, and the location of the incident within the work zone.

Statistics were broken down into a spreadsheet of each variable according to its "Case Number" and a 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 crash database statistics.

The narratives for each case provide a detailed description of the incident. Items that cannot be conveyed in the numerical data were 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 felt was important to the incident. This information could only be used as a qualitative or descriptive statistic and, like information provided by the TAC, would be used only to guide further investigations.

Data that were published by OSHA and Iowa OSHA were also carefully considered in this study. Two sets of data are published by OSHA and Iowa OHSA each year. The first dataset includes recordable case counts for each type of industry and the second dataset includes 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 were 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.

Pilot Project
A pilot project was 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 for this study was the Interstate 29 Expansion and Improvement project located in Sioux City, Iowa. Overall, the project includes widening the current interstate roadway, replacing several entry and exit ramps, and replacing several bridges. The focus of our study covers the Segment 1 portion that includes the widening of the current interstate system from four lanes to six lanes.

Key Findings

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. Given the category of highway, street, and bridge construction has a relatively small sample size for the total annual employment for Iowa, statistical variation was high in the Iowa data. Given a much larger population size is used for national incident rates, Iowa statistics can be compared to the linear model developed in this study.

In more than half the years included in the study, Iowa has 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 finding 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 for future research.

One positive that can be identified is that models for both Iowa and national incident rates are downward sloping. The model for total recordable cases offers the best evidence that overall incident rates for Iowa are improving from year to year. The linear models also display similar slopes in the downward trends for each analysis that was performed.

Iowa DOT Crash Database
The Iowa DOT crash database provided a way to categorize incidents that are considered by a reporting officer to be work-zone-related:

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

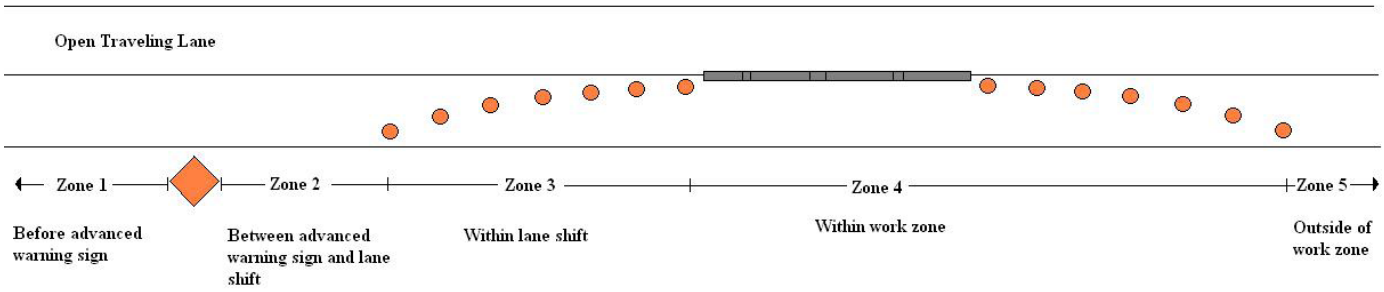
The TAC anticipated that the Zone 3 lane shift category was the cause for the most incidents and the most problematic area for heavy equipment. However, with the database query, the research team found not much difference between the number of incidents associated with Zones 2 and 3. Zone 2 had 42 incidents and Zone 3 had 37 incidents.

The significant majority of incidents occurring for heavy equipment are in Zone 4, accounting for 139 of the 229 total incidents. Zones 1 and 5 accounted for the fewest incidents for heavy equipment, 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 database serve as conflicting information in this study. In this case, further examination must be considered when analyzing these data.

The discrepancy could be a due to many different factors. One possible contributing factor to the conflicting evidence is that reporting officers may not be identifying the Iowa DOT-defined zones in which a work-zone-related incident is occurring consistently or correctly. 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, given each highway construction project is unique,



Iowa DOT construction "zones"

it would be difficult to identify comparable zones for each highway project.

Another likely factor for the significant majority of the incidents that occur in Zone 4 is the amount of exposure that the traveling public has in this zone. 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 job site length, it will have more incidents associated with it. This factor was identified as the most likely source of the discrepancy between expert panel experience and statistical data.

Incident Reports

Due to the conflicting evidence presented by the TAC and the Iowa DOT crash database, individual incident narratives were analyzed to supplement previous evidence. These individual reports included detailed information about each incident.

Within these narratives, it became clear that the Iowa DOT zone in which each incident occurred was not the only 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 line up of vehicles could then potentially lead to an incident that occurs in Zone 2 but, in effect, is an incident caused by activity in Zone 3. This situation is not accounted for in the classification of the location of the incident in the crash database. The data pointed toward 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 itself.

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. Given all except one respondent was a DOT respondent 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, combining the counts for 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, and particularly inspectors, 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 the job site or 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.

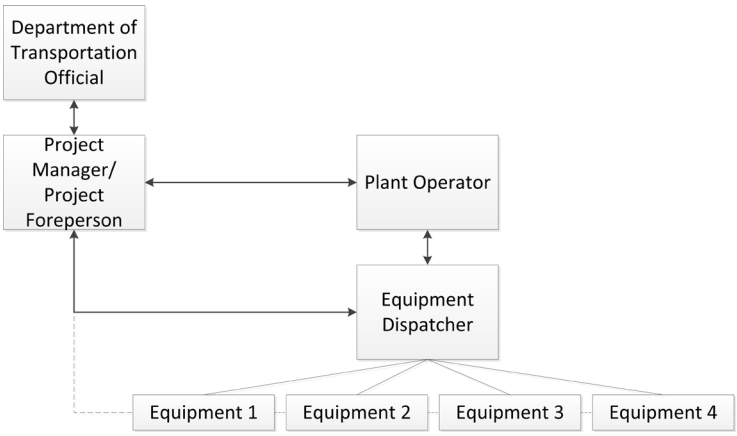
The second major category of responses for the survey addressed problems with ingress and egress by means of either extending distances for ingress and egress, so that drivers and operators are able to accelerate or decelerate, or providing an alternate route that is less congested by the traveling public. If either of these techniques can be implemented on a 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 for addressing ingress and egress safety improvement from the survey 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 zone improvements.

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 most "closed" work zones and standard traffic control plans are easier to implement. With an "open" work zone, many more unique situations that require an adapted traffic control plan are required.

Developing the Job-Site Communication Model

Through the solicitation of personal interviews and the insight provided by the TAC, a Lines of Communication Model was developed.



Sample job-site communication model

More specifically, job-site 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 found in the qualitative data collection interaction.

Included in the model are the roles of DOT officials, project managers, project forepersons, plant operators, equipment dispatchers, and equipment operators. Solid lines represent primary lines of communication and dashed lines represent secondary lines of communication.

In all highway construction projects, it is essential that lines of communication are thoroughly established and open. Conflicts often arise from parties not knowing whom to contact, or parties not forwarding relevant information to the proper people. Because of the volatility and ever-changing conditions of a job site, 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 forepeople 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.

Implementation Readiness and Recommendations

Implementation of recommended risk mitigation processes and strategies will be the responsibility of the Iowa DOT and/or other transportation agencies. The possible mitigation techniques were developed as a part of the pilot project by using field observations and interviews with pilot project personnel.

- OSHA and Iowa OSHA data should be used as a basis to compare safety on a statewide and 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.
- The Iowa DOT crash database has been an effective tool in analyzing incidents that are work-zone-related. At this time, incidents in the Iowa DOT Zone 4 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.
- The methods in which reporting officers identify the location of an incident within the Iowa DOT's defined Zones 1 through 5 in a work zone should be reviewed to ensure not only consistency in reporting, but also reporting of the Zone in which the cause of the incident occurred. In addition, the manner in which crash narratives are filled out for each incident is essential to identifying the major causes of each incident. Consistency is of the upmost importance when trying to normalize this data.
- Ingress and egress areas on construction job sites, as expressed by the TAC and during personal interviews, represent the most challenging areas to address work-zone safety and mobility. Although these areas do not represent the highest frequency of incidents, they were cited consistently by contractors, truck drivers, and Iowa DOT personnel throughout this study as the most difficult areas to control. 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 planning can be done not only for vehicles, but for material deliveries as well.
- Personal interviews with experts of various technical backgrounds are essential to formulate the basis of highway construction research. Given highway construction is such a dynamic industry subjected to so many unique project-level difficulties, it is difficult to normalize data. A mixed-methods approach, where qualitative assessments are used, is 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.
- Effective job-site communication was a theme that was encountered in almost every stage of this research project. More specifically, the individual interactions between plant operators, dispatch, forepersons, and drivers are the most crucial interactions that pertain to on-the-job work-zone safety and internal traffic control. To support these interactions, effective training programs and project-specific communication models should be developed so that roles and responsibilities of each party are clear.
- 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.

Research Limitations

The report details limitations of this research project.

Possible Future Research

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

Normalizing 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 Zones 1 through 5 of the work zone are difficult to compare given 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 of every highway construction project performed in a given year. Having this data would help to confirm or deny specific claims about which Iowa DOT 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, given the discrepancies discovered in this study. Inconsistencies in how each Iowa DOT Zone is identified in individual incident reports may be a 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 led to the inability to classify the incident. Without consistent reporting from all jurisdictions, it is difficult to normalize data and therefore is difficult to analyze data statistically because of these 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.